AD-A250 673

AL-TR-1991-0110

ARMSTRONG LABORATORY

THE EFFECT OF VARIABLE SEAT BACK ANGLES ON HUMAN RESPONSE TO +Gz IMPACT ACCELERATIONS

Chris E. Perry
Dena M. Bonetti
James W. Brinkley

CREW SYSTEMS DIRECTORATE
BIODYNAMICS AND BIOCOMMUNICATIONS DIVISION

MAY 1991

INTERIM REPORT FOR PERIOD 15 JULY 1986 TO APRIL 1991

Approved for public release; distribution is unlimited.

AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6573

NOTICES

TECHNICAL REVIEW AND APPROVAL

AL-TR-1991-0110

The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 169-3.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

Peter A. Lurker

PETER A. LURKER, Lt Col, USAF, BSC
Acting Director
Biodynamics and Biocommunications Division
Armstrong Laboratory

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
May 1991

3. REPORT TYPE AND DATES COVERED
Interim 15 July 86 - April 91

4. TITLE AND SUBTITLE
The Effect of Variable Seat Back Angles on Human Response To +Gz Impact Accelerations

5. FUNDING NUMBERS
PE - 62202F
PR - 7231
TA - 723124
WU - 72312401

6. AUTHOR(S)
Chris E. Perry
Dena M. Bonetti
James W. Brinkley

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Armstrong Laboratory, Crew Systems Directorate
Biodynamics and Biocommunications Division
HSD, AFSC,
Wright-Patterson AFB, OH 45433-6573

8. PERFORMING ORGANIZATION REPORT NUMBER
AL-TR-1991-0110

9. SP ORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE
A

13. ABSTRACT *(Maximum 200 words)*
During 1986-1987, eighty-two human impact experiments were accomplished on a vertical deceleration tower to determine the influence of variable seat back angles on human dynamic response to short-duration acceleration applied in the +x axis. Subjects were exposed to acceleration at a level of 10 G using a vertical deceleration tower. The seat back angle varied as follows: (1) +5° (5° aft of vertical), (2) 0° (vertical), (3) -5° (5° forward of vertical), and (4) -10° (10° forward of vertical). The resultant seat loads in the z-axis did not show statistically significant differences as the seat back angle was varied. Data showed a trend for head acceleration in the -x axis to increase and for head acceleration in the +x axis to decrease as the seat back angle became more negative. This implies that cervical spine flexion increases as the seat back angle becomes more negative. This is supported by motion analysis using high-speed photography which indicated a trend for increased forward rotation of the head as the seat back angle became more negative. These experimental data will be used in the formulation of biodynamic models.

14. SUBJECT TERMS
Impact Tests, Biodynamics, Seat Back Angle, Vertical Deceleration, Head/Neck Response, Off-Axis Impact, Cervical Spine

15. NUMBER OF PAGES
140

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

PREFACE

The tests described within this report were accomplished by the Escape and Impact Protection Branch, Biodynamics and Biocommunications Division, Crew Systems Directorate of the Armstrong Laboratory. The impact tests were conducted using a vertical deceleration tower to simulate the ejection impact acceleration.

The impact facilities, data acquisition equipment, and data processing system were operated by the Scientific Services Division of DynCorp under Air Force contract F33615-86-C-0531. Mr Marshall Miller was the engineering supervisor for DynCorp.

Photographic data and documentation services were provided by the Technical Photographic Division of the 4950th Test Wing.

TABLE OF CONTENTS

PREFACE iii
TABLE OF CONTENTS iv
LIST OF FIGURES v
LIST OF TABLES v

INTRODUCTION 1
METHODS 2
Experimental Design 2
Analysis 7
RESULTS 9
MEDICAL FINDING 24
CONCLUSIONS 26
REFERENCES 28

APPENDIX A. Data Acquisition System and Software 29
APPENDIX B. Representative Test Data 82

LIST OF FIGURES

FIGURE		PAGE
1	Seat Back Angle Postions	3
2	Pretest Position/Restraint of Subject	4
3	Pretest Position/Restraint of Subject	5
4	Fast Fourier Transform Plot of Input Acceleration	19
5	Fast Fourier Transform Plot of Output Acceleration	19
6	Plot of Head Transmissivity	20
7	Plot of Head Transmissivity Over Range of Maximum Input Energy	20
8	Time Domain Analysis Plot Showing Good Fit	21
9	Time Domain Analysis Plot Showing Lack of Fit for Input Response Greater Than 15 G	21

LIST OF TABLES

TABLE		PAGE
1	Experimental Conditions	2
2	Variable Seat Back Angle Evaluation With ACES II Seat Anthropometry of Test Subjects	6
3	Variable Seat Back Angle Evaluation With ACES II Seat Electronic Data Summary	9
4	Variable Seat Back Angle Evaluation With ACES II Seat Summary of Paired-Replicate Rank Test Analysis of Electronic Data	10
5	Head Motion Classification	11
6	Cervical Spine Flexion and Extension	12
7	Cervical Spine Flexion in Cells E and F	12
8	Cervical Spine Flexion in Cells E and G	12
9	Cervical Spine Flexion in Cells E and H	12
10	Cervical Spine Flexion in Cells F and G	13
11	Cervical Spine Flexion in Cells F and H	13
12	Cervical Spine Flexion in Cells G and H	13
13	Cervical Spine Extension in Cells E and F	14
14	Cervical Spine Extension in Cells E and G	14
15	Cervical Spine Extension in Cells E and H	14
16	Cervical Spine Extension in Cells F and G	15
17	Cervical Spine Extension in Cells F and H	15
18	Cervical Spine Extension in Cells G and H	15
19	Variable Seat Back Angle Evaluation with ACES II Seat Resultant Maximum Displacement	16
20	Variable Seat Back Angle Evaluation with ACES II Seat Wilcoxon Paired-Replicate Rank Analysis of Resultant Maximum Displacement	17
21	Variable Seat Back Angle Evaluation with ACES II Seat Transfer Function Analysis of Z Axis Head Acceleration	22
22	Variable Seat Back Angle Evaluation with ACES II Seat Transfer Function Analysis of Z Axis Head Acceleration Wilcoxon Paired-Replicate Rank Test (Two-Tailed)	22
23	Variable Seat Back Angle Evaluation with ACES II Seat Time Domain Analysis of Z Axis Head Acceleration	23
24	Variable Seat Back Angle Evaluation with ACES II Seat Time Domain Analysis of Z Axis Head Acceleration Wilcoxon Paired-Replicate Rank Test (Two-Tailed)	23
25	Variable Seat Back Angle Evaluation with ACES II Seat Comparison of Subject M22 Data with Average Cell E Data Acceleration Level 10 G, +Z Axis, PCU-15/P Restraint Harness	25

INTRODUCTION

One of the main risks to pilots during emergency escape from a high-performance aircraft is a vertebral fracture due to the impact acceleration imposed on the spinal column. Frequently, the acceleration vector during ejection is not aligned parallel with the long axis of the vertebral column but is off-axis because of the initial body position or because of the alignment of the ejection seat's thrust vector. The off-axis forces on the vertebral column can be divided into two components; a compressive force parallel to the long axis of the spine, and a shear force perpendicular to the long axis of the spine.

The effects of these off-axis forces on the vertebral column during ejection are not known; therefore, this research effort was conducted to evaluate the human dynamic response to a +Gz acceleration using a variable seat back angle to allow for off-axis impacts. Collected data will be used in the development of biodynamic models and as additional experimental information for inclusion into a database for the design of future escape systems.

METHODS

Experimental Design

Impact tests were performed using a vertical deceleration tower facility. The test conditions are shown in Table 1. The first impact for each subject was an 8 G orientation test. The remaining test conditions were presented to the subjects in a randomized fashion. Other test conditions such as acceleration time history, pre-impact position, and the restraint configuration used to secure the subject were controlled to assure that the measured responses were due primarily to the variable seat back angle.

TABLE 1. EXPERIMENTAL CONDITIONS

TEST CELL	ACCELERATION LEVEL	SEAT BACK ANGLE
W	8 G	0°
E	10 G	+5°
F	10 G	0°
G	10 G	-5°
H	10 G	-10°

A generic seat design with an ACES II seat cushion was used for all of the tests. The seat was designed to withstand vertical impacts up to 50 G and has an adjustable seat back allowing the subject to sit in one of four different positions. The positions are shown in Figure 1. The four different positions allowed the study of various off-axis impact acceleration profiles. No footrest structure or leg restraint was provided so the lower legs were positioned during the test as shown in Figure 1. The subjects were restrained in the seat by the PCU-15/P torso/parachute harness and a 1 3/4 inch wide lap belt. Before each test, the restraint system (lap belt and shoulder strap) was preloaded to 20 ± 5 lb (89 ± 22 N). All subjects wore a HGU-26/P flight helmet and were initially positioned with the head upright, helmet against the headrest and arms resting on the thighs. The pretest position of the subject is shown in Figures 2 and 3.

The volunteer subjects, 16 men and 2 women, were active duty officers and enlisted personnel at Wright-Patterson Air Force Base who were medically qualified for impact acceleration stress experiments and were members of the Laboratory impact acceleration stress panel. The subjects were required to meet anthropometric criteria for USAF pilots and have a medical screening more stringent than a USAF flying class II examination. Table 2 summarizes the anthropometry of the test subjects used for this study.

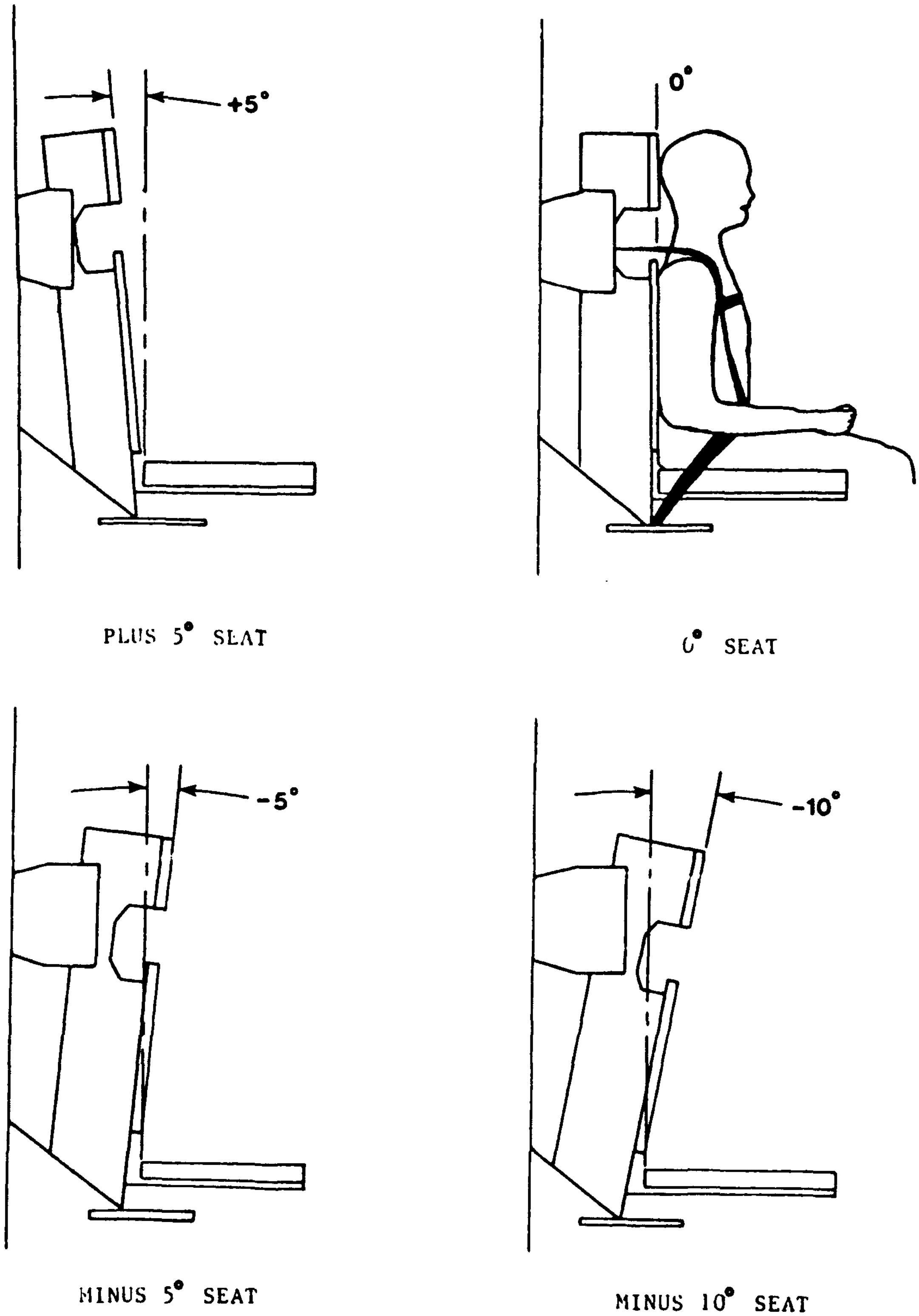


FIGURE 1. SEAT BACK ANGLE POSITIONS

Figure 2. Pretest Position/Subject Restraint

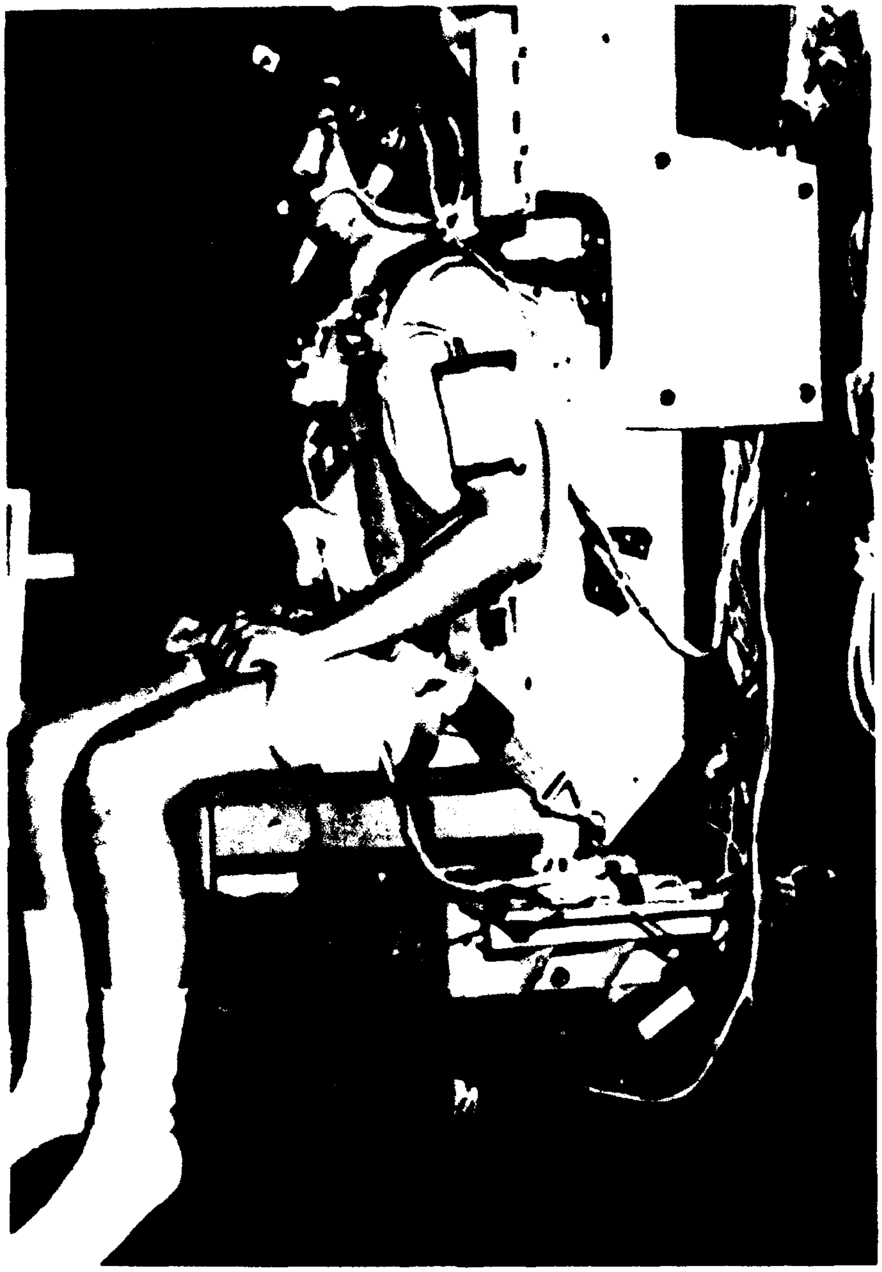


Figure 3. Pretest Position/Subject Restraint

TABLE 2
VARIABLE SEAT BACK ANGLE EVALUATION WITH ACES II SEAT
ANTHROPOMETRY OF TEST SUBJECTS

SUBJ NO.	WT (lb)	STATURE (in)	SITTING HEIGHT (in)	MID-SHOULDER SITTING HEIGHT (in)	BUTTOCK TO KNEE (in)	AGE (yr)
B-1	160	70.5	37.1	25.7	23.9	28
D-3	198	73.1	38.0	26.6	25.5	24
D-5	175	72.0	36.1	25.0	25.0	25
L-3	190	72.0	37.4	26.1	25.1	36
L-5	186	69.8	35.6	25.4	25.1	27
M-16	199	70.0	37.3	25.7	24.6	32
M-19	181	74.2	38.5	26.1	25.6	26
M-20	199	70.8	37.0	26.0	25.0	29
M-21	126	66.0	34.1	23.5	23.0	28
*M-22	139	70.0	35.9	25.0	24.3	26
O-2	178	65.7	34.0	24.0	23.6	26
P-5	186	68.5	36.0	24.6	23.2	25
R-8	169	74.6	37.6	26.3	26.4	28
S-3	167	69.5	36.5	25.5	23.7	38
S-8	214	72.8	37.3	26.3	25.8	27
Z-2	143	68.3	36.9	25.4	22.9	26
MEAN	176	70.5	36.6	25.5	24.5	28
S.D.	24	2.60	1.26	0.86	1.07	4
1967 USAF FLIGHT SURVEY MEAN	174	69.8	36.7	25.4	23.8	30
S.D.	21	2.40	1.30	1.10	1.10	6

* COMPLETED TEST CELL E ONLY

The tests were conducted using presumed subinjury, short duration acceleration conditions produced using the Armstrong Laboratory's Vertical Deceleration Tower (VDT). The generic seat was mounted on the VDT's impact carriage which was raised and then allowed to free fall along vertical rails into a hydraulic decelerator at the base of the tower. Before the carriage was allowed to free fall, it was raised to a height of 8.4 feet for the 8 G orientation tests and to a height of 10.8 feet for the 10 G experimental tests. To assure identical acceleration conditions, the carriage drop height (approximate), test assembly mass, water volume and plunger type were the same for all experimental level tests. The Automatic Data Acquisition and Control System (ADACS), also mounted on the carriage, was used to collect data. Parameters included the carriage and seat accelerations, seat pan forces, restraint forces, translational accelerations, and angular accelerations about the y axis, of each subject's head and chest. Refer to Appendix B for examples of the ADACS data packages. Photogrammetric data were also collected using high-speed film allowing the measurement of body kinematics. The electronic and photogrammetric data acquisition system is described in detail in Appendix A.

Analysis

The left-handed coordinate reference system for acceleration (+x anterior, +z cephadalad) was used during data analysis. Digital Equipment Corporation PDP-11/34 and VAX 11/750 computers were used to process the electronic and photogrammetric data.

The electronic data were evaluated using the Wilcoxon paired-replicate rank test. This technique was selected to compare the peak values of measured parameters and to determine the statistical significance of the data. This approach makes each subject his own control thereby accounting for biological variability among subjects. The 95th percent confidence level ($\alpha = 0.05$) was chosen assuming a two-tailed test. Because of the nature of the Wilcoxon paired-replicate rank test, only data from the fifteen subjects who completed all of the test cells were used in the Wilcoxon analysis.

The null hypothesis that was statistically evaluated was that there are no differences between measured human dynamic response parameters regardless of the seat back angle used. Key parameters included seat load (z axis), shoulder loads (x axis, z axis, and resultant), head acceleration (x axis, z axis, and angular) and chest acceleration (x axis and z axis).

In addition to the electronic data analysis, the photogrammetric data were analyzed using two techniques. The first analysis involved the documentation of gross head movement and then classification of the head motion. This was done by observing the high-speed film of each subject on a 16mm film projector possessing single-frame viewing. The second analysis consisted of reviewing the maximum displacement values of each photogrammetric fiducial (film target). The displacement values were determined through the x-y coordinate digitization of each subject's high-speed film. The results of the head motion classification and the displacement analysis were statistically evaluated using the Wilcoxon paired-replicate rank test as used with the electronic data.

The final analysis of the test results involved the natural frequency and damping ratio of the human head and chest (torso) as a function of the seat back angle. The frequency and damping ratio were calculated using two different techniques: the frequency domain (transfer function evaluation) technique and the time domain (curve fitting) technique.

These two techniques will be discussed further in the Results section. The variation of the these parameters as a function of seat back angle was analyzed using the Wilcoxon paired-replicate rank test as identified previously.

In addition, a short synopsis will be given on the occurrence of an end-plate vertebral fracture in an experimental subject at the 10 G impact level. The discussion will include a brief desciption of the injury as well as an analysis of a possible mechanism of injury.

RESULTS

The electronic data of the pertinent parameters are summarized in Table 3 in terms of the means and standard deviations of measurements for the evaluation of each of four seat back angles. Appendix B provides typical sets of electronic data from tests of each seat back angle and the maxima and minima of each measurement.

The seat acceleration for tests in this study was well controlled throughout the evaluation. The means and standard deviations for this parameter are also shown in Table 3.

TABLE 3
VARIABLE SEAT BACK ANGLE EVALUATION WITH ACES II SEAT
ELECTRONIC DATA SUMMARY

RESPONSE PARAMETER	CELL E	CELL F	CELL G	CELL H
SEAT ACCELERATION (G) Z AXIS	10.73 ± 0.29	10.64 ± 0.38	10.67 ± 0.30	10.48 ± 0.14
SHOULDER LOADS (lb)				
X AXIS	169.90 ± 55.96	185.72 ± 71.09	212.49 ± 60.25	241.20 ± 68.09
Z AXIS	50.24 ± 23.05	44.26 ± 20.67	35.14 ± 19.05	29.79 ± 17.18
RESULTANT	177.40 ± 58.52	191.11 ± 72.45	216.09 ± 60.13	243.56 ± 68.09
SEAT LOAD (lb) RESULTANT	2648.63 ± 392.05	2698.15 ± 362.13	2722.30 ± 347.80	2726.95 ± 319.67
CHEST ACCELERATION (G)				
X AXIS	4.36 ± 1.88	4.17 ± 1.83	3.76 ± 1.61	3.64 ± 1.74
Z AXIS	15.65 ± 1.63	15.89 ± 2.14	16.88 ± 2.40	16.46 ± 1.82
HEAD ACCELERATION (G)				
X AXIS	2.61 ± 1.28	2.44 ± 1.08	2.36 ± 0.99	1.81 ± 0.94
-X AXIS	1.26 ± 1.20	2.00 ± 1.28	2.69 ± 1.05	3.84 ± 1.23
Z AXIS	13.63 ± 1.36	13.54 ± 1.30	13.48 ± 1.42	13.42 ± 1.70
ANGULAR (Ry)	264.04 ±123.67	211.15 ± 77.43	243.43 ± 85.76	217.61 ± 67.55

CELL E: SEAT BACK ANGLE +5°
CELL F: SEAT BACK ANGLE 0°
CELL G: SEAT BACK ANGLE -5°
CELL H: SEAT BACK ANGLE -10°

The results of the Wilcoxon analysis comparisons are summarized in Table 4. In each cell-to-cell comparison, the "I" or "D" indicates the trend of the magnitude of the parameter to increase or decrease. Where these trends are statistically significant, the percentage shown is the confidence level given to the statistically significant difference in the response parameter for a given comparison.

TABLE 4
VARIABLE SEAT BACK ANGLE EVALUATION WITH ACES II SEAT SUMMARY OF WILCOXON PAIRED REPLICATE TEST ANALYSIS OF ELECTRONIC DATA

RESPONSE PARAMETER	E - F	E - G	E - H	F - G	F - H	G - H
SHOULDER LOAD (lb)						
X AXIS	I 99%	I 99%	I 99%	I 99%	I 99%	I 99%
Z AXIS	D 95%	D 99%	D 99%	D 99%	D 99%	D 99%
RESULTANT	I 98%	I 98%	I 98%	I 98%	I 98%	I 98%
RESULTANT SEAT LOAD (lb) (lb)	I	I	I	I	I	I
CHEST ACCELERATION (G)						
X AXIS	D	D	D	D	D	D
Z AXIS	I	I	I	I	I	I
HEAD ACCELERATION (G)						
X AXIS	D	D	D 99%	D	D 98%	D
-X AXIS	I 95%	I 98%	I 98%	I 98%	I 98%	I 98%
Z AXIS	D	D	D	I	D	-
ANGULAR (R)	D	D	D	I	I	I

I INDICATES A TREND TO INCREASE AND D INDICATES A TREND TO DECREASE FROM CELL TO CELL.

CELL E: SEAT BACK ANGLE +5°
CELL F: SEAT BACK ANGLE 0°
CELL G: SEAT BACK ANGLE -5°
CELL H: SEAT BACK ANGLE -10°

Comparison of the measured shoulder loads showed a statistically significant increase in the x-direction and resultant forces and a statistically significant decrease in the z-direction forces as the seat back angle became more negative. Comparison of the resultant seat loads did not reveal a statistically significant difference as the seat back angle was varied. While the chest acceleration showed a trend to decrease in the x axis and increase in the z axis as the seat back angle became more negative, neither trend was significant statistically. Comparisons of the head accelerations revealed a statistically significant increase in the -x axis acceleration as the seat back angle became more negative. A statistically significant decrease in the x axis head acceleration was shown in the E-H (5° aft of vertical to 10° forward of vertical) and F-H (vertical to 10° forward of vertical) comparisons. Comparisons of head acceleration in the +x axis indicated a slight trend to decrease as the seat back angle became more negative, but this trend was not statistically significant. Angular head acceleration showed a trend to decrease in the E-F (5° aft of vertical to vertical), E-G (5° aft of vertical to 5° forward of vertical), and E-H (5° aft of vertical to 10° forward of vertical) comparisons. Angular head acceleration showed a trend to increase in the F-G (vertical to 5° forward of vertical), F-H (vertical to 10° forward of vertical) and G-H (5° forward of vertical to 10° forward of vertical) comparisons.

High-speed films were reviewed subjectively to classify gross head motion into one of five types: (1) Forward and Downward Rotation, (2) Forward Translation, (3) No Significant Movement (vertical only), (4) Forward Translation, then Rearward Rotation, and (5) Rearward Rotation. These data are summarized in Table 5. Cervical spine flexion was presumed to occur when there was either forward and downward rotation or forward translation of the head. Cervical spine extension presumably occurred when the head underwent forward translation, then rearward rotation or rearward rotation only.

TABLE 5
HEAD MOTION CLASSIFICATION

MOTION TYPE	NUMBER PER CELL (SEAT BACK ANGLE)				
	E (+5°)	F (0°)	G (-5°)	H (-10°)	TOTAL
FORWARD TRANSLATION, DOWNWARD ROTATION	1	1	3	5	10
FORWARD TRANSLATION	0	3	3	6	12
NO SIGNIFICANT MOVEMENT	9	8	3	2	22
FORWARD TRANSLATION, REARWARD ROTATION	1	0	4	2	7
REARWARD ROTATION	6	3	2	0	11
TOTAL	17	15	15	15	62

The Yates Chi-square test was used to evaluate the correlation between cervical spine flexion or extension and the seat back angle. Table 6 shows the incidence of cervical spine flexion and extension in each test cell. Tables 7-12 show pertinent 2 X 2 contingency tables for cervical spine flexion. The null hypothesis that the rate of cervical spine flexion does not increase as the seat back angle becomes more negative can be rejected in comparison E-H (5° aft of vertical to 10° forward of vertical). This indicates that the cervical spine flexion rate increases as the seat back angle is moved forward of vertical with a total change of 15°. This analysis assumes equivalent populations and a 95% confidence limit (α = 0.05). Pertinent contingency tables for cervical spine extension are shown in Tables 13-18. The null hypothesis that the rate of cervical spine extension does not decrease as the seat back angle becomes more negative can be accepted, assuming a 95% confidence limit (α = 0.05).

TABLE 6
CERVICAL SPINE FLEXION AND EXTENSION

		NUMBER PER TEST CELL E (+5°)	F (0°)	G (-5°)	H (-10°)	TOTAL
CERVICAL SPINE FLEXION	NO	16	11	9	4	40
	YES	1	4	6	11	22
	TOTAL	17	15	15	15	62
CERVICAL SPINE EXTENSION	NO	10	12	9	13	44
	YES	7	3	6	2	18
	TOTAL	17	15	15	15	62

TABLE 7 CERVICAL SPINE FLEXION IN CELLS E AND F

		SEAT BACK ANGLE +5°	0°	TOTAL
CERVICAL SPINE FLEXION	NO	16	11	27
	YES	1	4	5
TOTAL		17	15	32

TABLE 8 CEVICAL SPINE FLEXION IN CELLS E AND G

		SEAT BACK ANGLE +5°	-5°	TOTAL
CERVICAL SPINE FLEXION	NO	16	9	25
	YES	1	6	7
TOTAL		17	15	32

TABLE 9 CERVICAL SPINE FLEXION IN CELLS E AND H

		SEAT BACK ANGLE +5°	-10°	TOTAL
CERVICAL SPINE FLEXION	NO	16	4	20
	YES	1	12	13
TOTAL		17	16	33

TABLE 10 CERVICAL SPINE FLEXION IN CELLS F AND G

		SEAT BACK ANGLE 0°	-5°	TOTAL
CERVICAL SPINE FLEXION	NO	11	9	20
	YES	4	6	10
TOTAL		15	15	30

TABLE 11 CERVICAL SPINE FLEXION IN CELLS F AND H

		SEAT BACK ANGLE 0°	-10°	TOTAL
CERVICAL SPINE FLEXION	NO	11	4	15
	YES	4	11	15
TOTAL		15	15	30

TABLE 12 CERVICAL SPINE FLEXION IN CELLS G AND H

		SEAT BACK ANGLE -5°	-10°	TOTAL
CERVICAL SPINE FLEXION	NO	9	4	13
	YES	6	11	17
TOTAL		15	15	30

TABLE 13 CERVICAL SPINE EXTENSION IN CELLS E AND F

		SEAT BACK ANGLE +5°	0°	TOTAL
CERVICAL SPINE EXTENSION	NO	10	12	22
	YES	7	3	10
TOTAL		17	15	32

TABLE 14 CERVICAL SPINE EXTENSION IN CELLS E AND G

		SEAT BACK ANGLE +5°	-5°	TOTAL
CERVICAL SPINE EXTENSION	NO	10	9	19
	YES	7	6	13
TOTAL		17	15	32

TABLE 15 CERVICAL SPINE EXTENSION IN CELLS E AND H

		SEAT BACK ANGLE +5°	-10°	TOTAL
CERVICAL SPINE EXTENSION	NO	10	14	24
	YES	7	2	9
TOTAL		17	16	33

TABLE 16 CERVICAL SPINE EXTENSION IN CELLS F AND G

		SEAT BACK ANGLE 0°	15°	TOTAL
CERVICAL SPINE EXTENSION	NO	12	9	21
	YES	3	6	9
TOTAL		15	15	30

TABLE 17 CERVICAL SPINE EXTENSION IN CELLS F AND H

		SEAT BACK ANGLE 0°	-10°	TOTAL
CERVICAL SPINE EXTENSION	NO	12	13	25
	YES	3	2	5
TOTAL		15	15	30

TABLE 18 CERVICAL SPINE EXTENSION IN CELLS G AND H

		SEAT BACK ANGLE -5°	-10°	TOTAL
CERVICAL SPINE EXTENSION	NO	9	13	22
	YES	6	2	8
TOTAL		15	15	30

High-speed films were also quantitatively analyzed for resultant displacement of the subject's head during impact at the various seat back angles. The displacements were found by first digitizing the high speed films (both the 90° perpendicular camera and the 45° oblique camera films). This process involves the x-y coordinate tracking of specified points of interest on the subject. This tracking process is done on each frame of film for each impact test. The digitization of the film allows tracking of the motion of the points of interest during the actual test, and by combining the tracking from the two cameras, the displacement of the points of interest can be determined in the three-dimensional space. The primary point of interest for this test program was the displacement of the subject's head during the impact. Four points on the subject's head and helmet were marked with fiducials. These were tracked along with a fiducial on the subject's chest as a point of reference. Figure 12 in Appendix A provides a complete diagram of all the fiducial locations. Table 19 provides a summary of the resultant displacements of the four head/helmet fiducials as well as for the chest fiducial for each of the seat back angles at the 10G impact level.

TABLE 19
VARIABLE SEAT BACK ANGLE EVALUATION WITH ACES II SEAT
RESULTANT MAXIMUM DISPLACEMENT

	CELL E (inches)	CELL F (inches)	CELL G (inches)	CELL H (inches)
HELMET 1	3.647 ±1.936 n = 16	4.339 ±2.168 n = 14	5.305 ±3.411 n = 13	5.929 ±3.308 n = 13
HELMET 2	3.097 ±1.529 n = 16	3.507 ±1.670 n = 15	4.165 ±2.285 n = 14	4.581 ±2.511 n = 15
CHEEK	2.292 ±0.788 n = 16	2.265 ±0.712 n = 15	2.656 ±0.945 n = 15	2.754 ±0.915 n = 15
MOUTH	2.052 ±0.978 n = 16	2.273 ±0.950 n = 15	2.606 ±1.356 n = 15	2.801 ±1.389 n = 15
CHEST	1.651 ±0.443 n = 16	1.656 ±0.423 n = 15	1.701 ±0.498 n = 12	1.894 ±1.050 n = 15

CELL E: SEAT BACK ANGLE +5°
CELL F: SEAT BACK ANGLE 0°
CELL G: SEAT BACK ANGLE -5°
CELL H: SEAT BACK ANGLE -10°

NOTE: THE NUMBER OF SUBJECTS FOR EACH PARAMETER AND CELL COMBINATION DIFFERS DUE TO THE UNAVAILABILITY OF PHOTO DATA FOR SOME SUBJECTS.

Measurement of both upper and frontal helmet fiducial displacements showed that the seat-back angle of +5° allowed the least amount of movement, but as the seat-back rotated from aft to fore of 0°, the displacement increased. The overall displacement of the upper fiducial was greater than the frontal indicating that the head/helmet motion was more rotation than translation. The cheek and mouth fiducials followed the same trends as the upper and frontal helmet fiducials respectively. It is interesting to note that the fiducials closer to the point of rotation of head (occipital condyle) had less displacement than the fiducials farther away (upper helmet fiducial, mouth fiducial). This also indicates the trend for the head to rotate and translate as opposed to translate only.

Examination of the displacement of the chest indicates that there was little difference among the measurements at the various seat-back angles. This indicates that the torso did not influence the movement of the head to any extent.

A statistical evaluation using the Wilcoxon analysis was completed with the head displacement data. The results are summarized in Table 20. The results show levels of significance of 90% or greater, or no significance at all. It is interesting to note that when the shift in angle was 10° or greater and transversed the 0° seat back line, all the head displacement data were significant. It should also be noted that the sample sizes are smaller than the actual number of subjects tested in each cell because the Wilcoxon requires that the same subjects be compared in each grouping of cell comparisons.

TABLE 20
VARIABLE SEAT BACK ANGLE EVALUATION WITH ACES II SEAT
WILCOXON PAIRED-REPLICATE RANK TEST ANALYSIS
OF RESULTANT MAXIMUM DISPLACEMENT

	SAMPLE SIZE	LEVEL OF SIGNIFICANCE					
		E – F	E – G	E – H	F – G	F – H	G – H
HELMET 1	12	I	I 98%	I 98%	I	I	I
HELMET 2	14	I	I 98%	I 98%	I	I	I
CHEEK	15	I	I 98%	I 98%	I 90%	I 98%	I
MOUTH	15	I 98%	I 98%	I 98%	I	I	I
CHEST	12	D	D	I	D	I	I

I INDICATES A TREND TO INCREASE; D INDICATES A TREND TO DECREASE.

E: SEAT BACK ANGLE +5°
F: SEAT BACK ANGLE 0°
G: SEAT BACK ANGLE -5°
H: SEAT BACK ANGLE -10°

To evaluate the frequency response of the volunteer subject's head as a function of seat-back angle, two different techniques (frequency analysis and time-domain analysis) were used. Each technique and its results will be discussed. Although each technique will be briefly described, in-depth discussion is beyond the scope of this report. It is hoped that if further information is required, the reader will consult the appropriate references.

The frequency domain analysis or "transfer function" analysis as it is often called is based upon a single degree of freedom linear model often called a "lumped parameter" model. The model is composed of a dashpot and a spring and is therefore adequately identified by the "natural frequency" and "damping ratio" parameters. The analysis consists of finding the fast fourier transform (FFT) of the input signal, in this case the seat +Gz acceleration, and the FFT of the output, in this case the head +Gz acceleration. The output FFT is then divided by the input FFT and the resultant plot of magnitude ratio vs frequency is called the transmissivity. From this transmissivity plot, the natural frequency and damping ratio of the modeled system, in this case the subject's head, can be obtained. One drawback of this technique is that the natural frequency is determined by the peak magnitude ratio on the magnitude ratio vs frequency plot; however, the peak magnitude ratio could be at a point on the plot where there is very little energy on the original FFT plots of the input and the output (essentially noise). Therefore, the investigator must be careful and pick the peak magnitude ratio in the frequency domain of maximum energy on the input and output FFT plots. See Figures 4 through 7 for an example of this case. Notice in Figures 4 and 5 that most of the energy in the plots is in the domain from 0 to approximately 12 hz; however, notice the transmissivity in Figure 6 has a peak at around 15 hz where the input has very little energy. Figure 7 shows a section of the transmissivity plot in the frequency range of maximum energy and you can see a peak at approximately 10.5 Hz which for this case was selected to be the natural frequency of the head. A summary of the natural frequencies and damping ratios as a function of seat-back angle is provided in Table 21 with a Wilcoxon analysis following in Table 22. Again as noted with the head motion analysis, the parameters show significant change when the seat-back rotates forward from the +5° position to any of the other positions, but is not significant when the initial position is 0° or greater and the seat-back rotates forward. A few exceptions occur with the damping ratio at the 0° to -5° seat-back angle comparison (Cell F and H respectively).

The time domain analysis or curve fitting technique is another method used to determine the frequency response of a system. Like the transfer function analysis, the time domain analysis is also based upon a single degree of freedom linear model composed of a dashpot and a spring. As the other name implies, this analysis technique uses trial and error to match the peak magnitude and rise time of a test subject's +Gz head acceleration plot (output response). The curve fitting continues until the error in the peak acceleration and the rise time is minimized. At that point, the natural frequency and damping ratio are calculated. Plots of this method are shown in Figures 8 and 9 for z-axis head accelerations. The drawback of this technique is that for modeling the response of the head, as the +Gz head acceleration increases to 15 G or greater, the lumped parameter model becomes unstable and is unable to match peak magnitude. Also at this point, the damping ratio becomes 0 further indicating the inability of the model to match the output response. When this inability to match magnitudes occurs, it suggests that the system is no longer a linear system and cannot be modeled by lumped parameters (dashpot and spring). However, even though the peak is not matched, further investigation is required to determine the accuracy of the predicted natural frequency and damping ratio using the time domain technique. A summary of the results can be found in Table 23, and a Wilcoxon analysis can be found in Table 24.

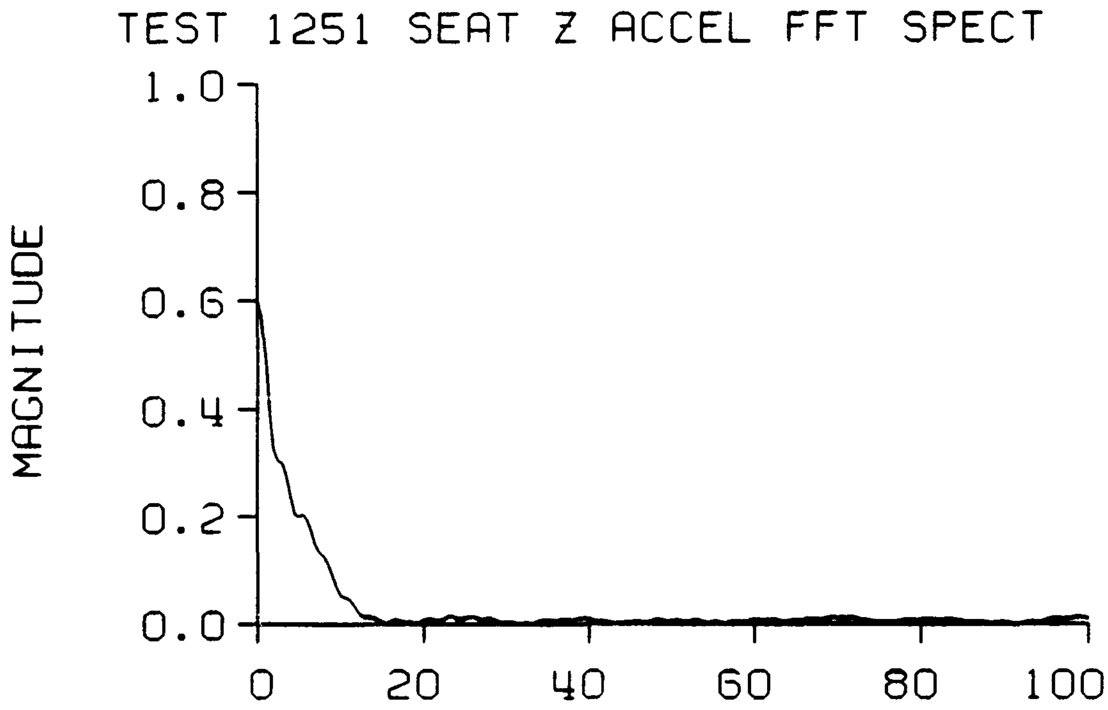


FIGURE 4. FAST FOURIER TRANSFORM PLOT OF INPUT ACCELERATION

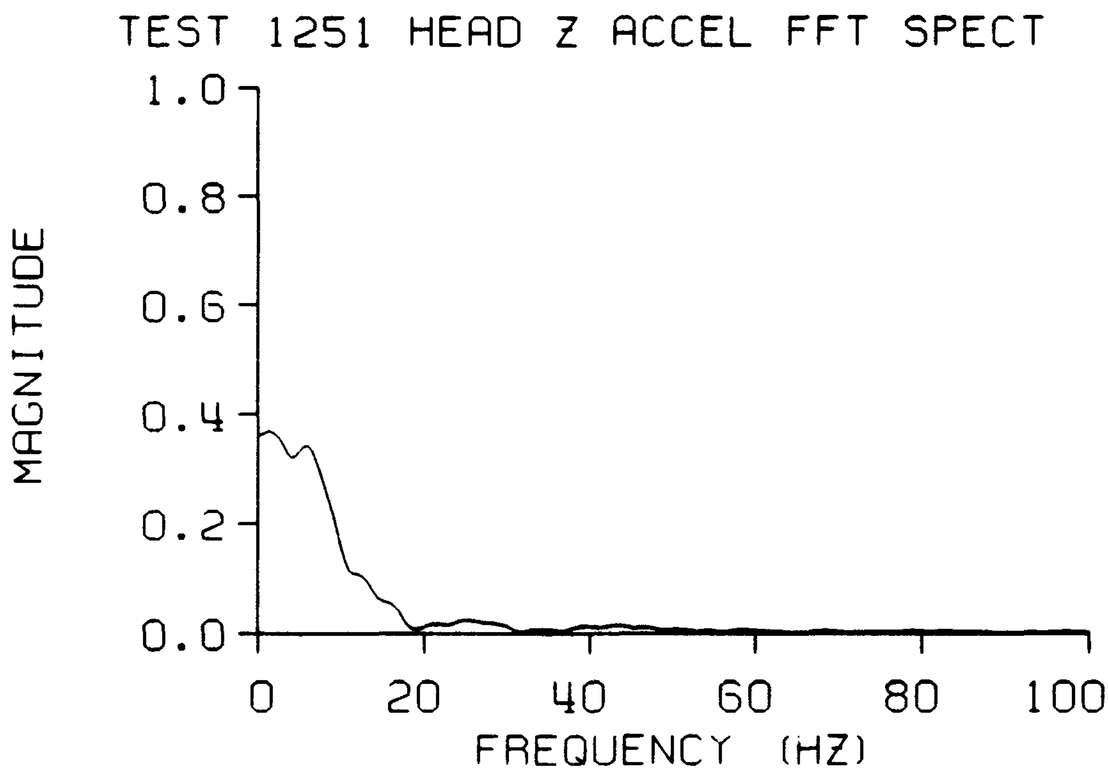


FIGURE 5. FAST FOURIER TRANSFORM PLOT OF OUTPUT ACCELERATION

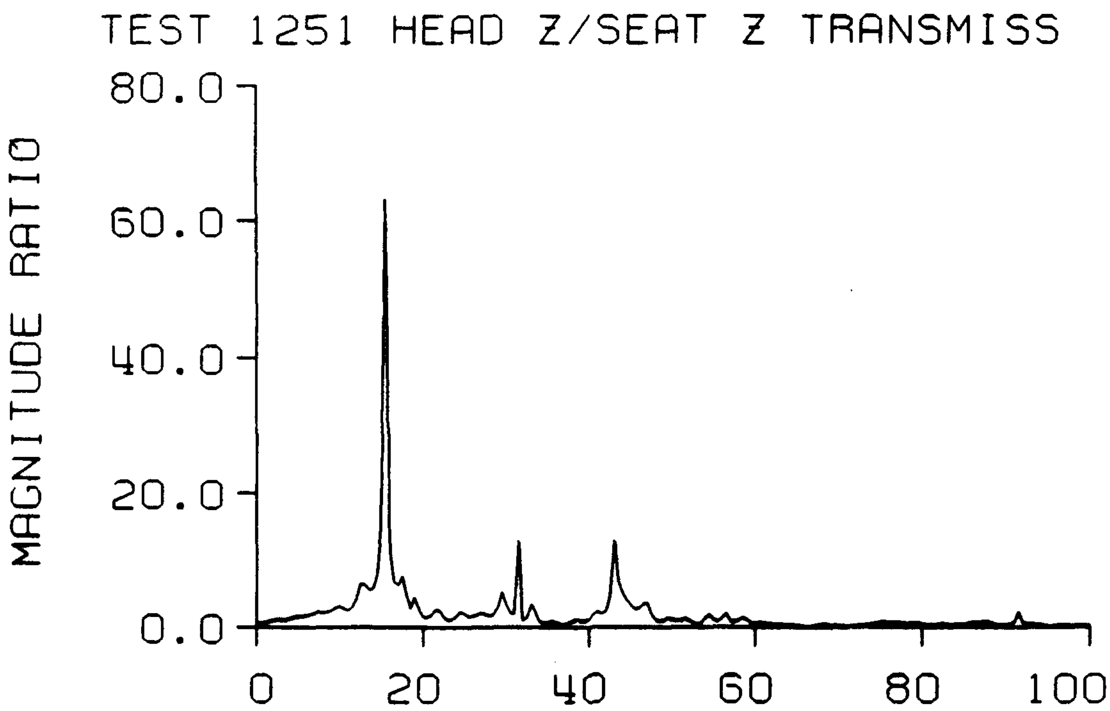


FIGURE 6. PLOT OF HEAD TRANSMISSIVITY

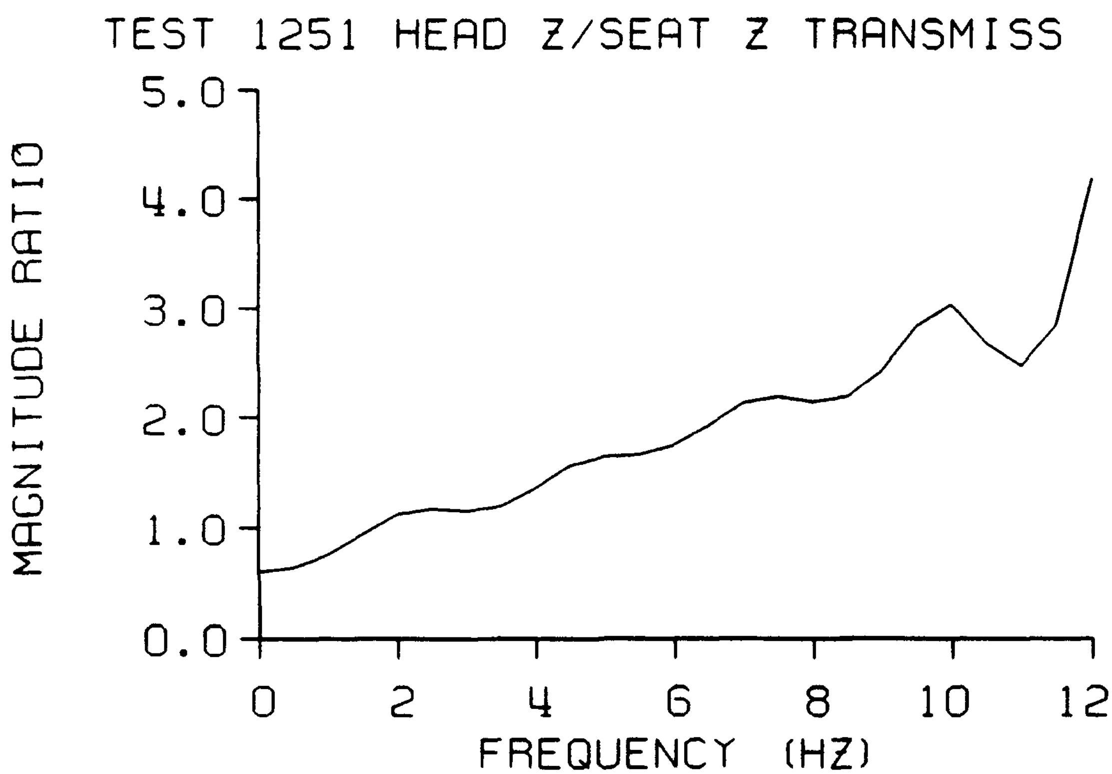


FIGURE 7. PLOT OF HEAD TRANSMISSIVITY OVER RANGE OF MAXIMUM INPUT ENERGY

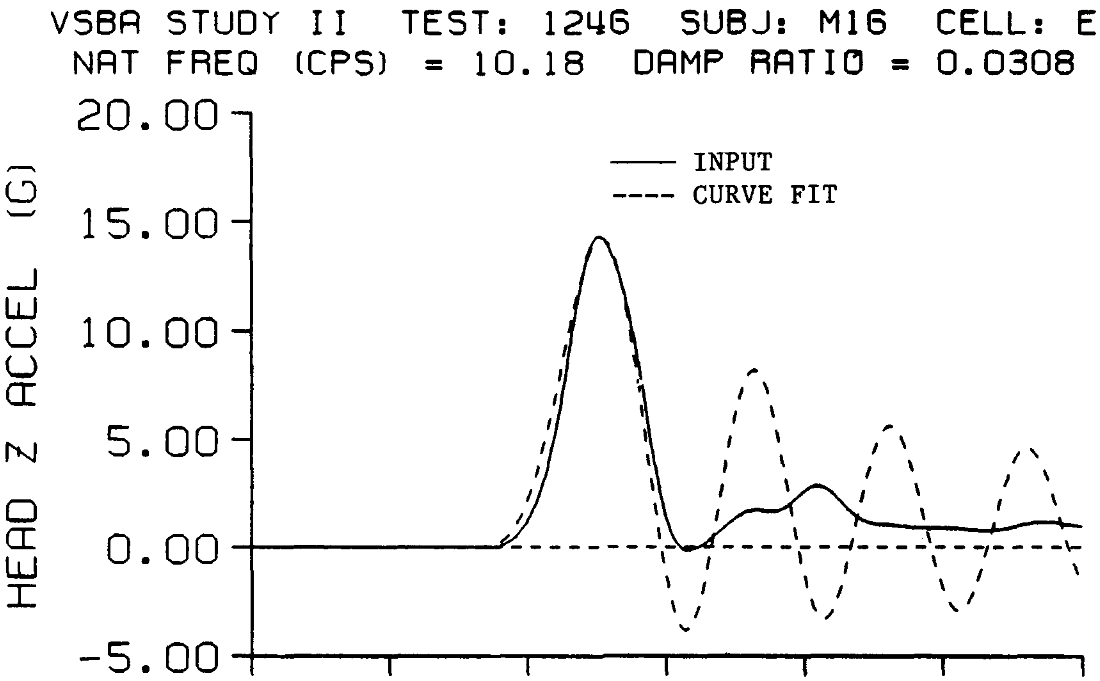


FIGURE 8. TIME DOMAIN ANALYSIS PLOT SHOWING GOOD FIT

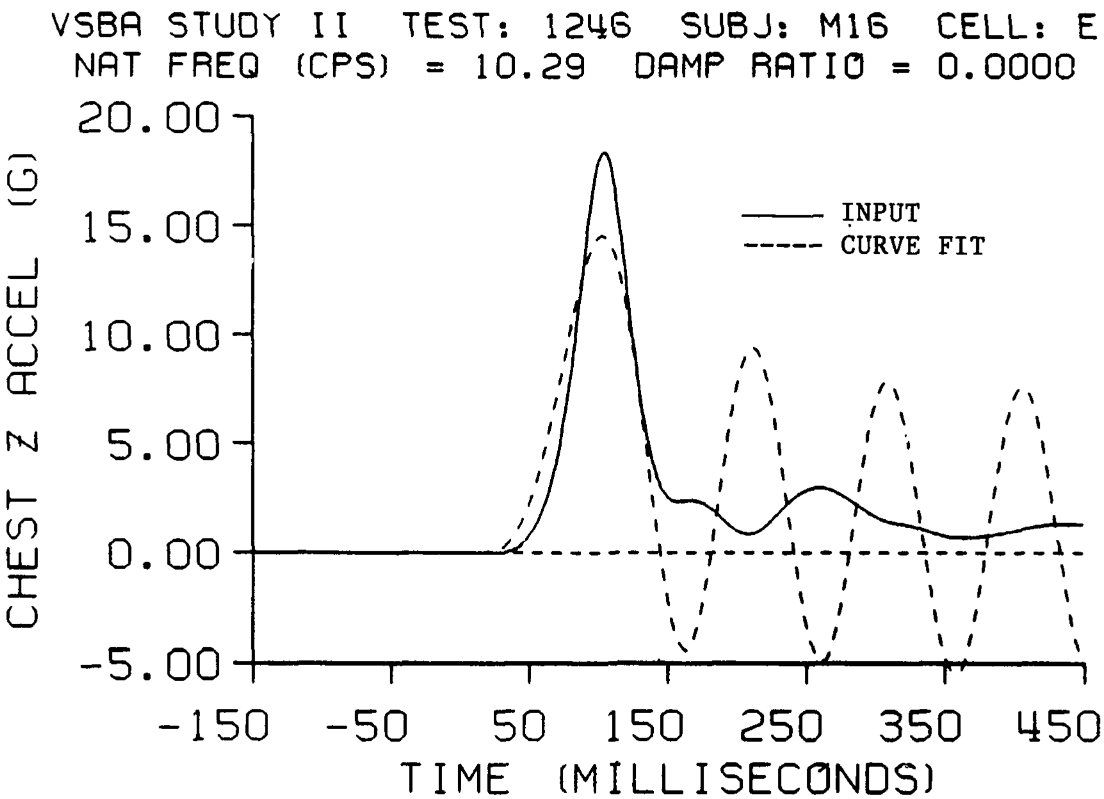


FIGURE 9. TIME DOMAIN ANALYSIS PLOT SHOWING LACK OF FIT FOR INPUT RESPONSE GREATER THAN 15 G

TABLE 21
VARIABLE SEAT BACK ANGLE EVALUATION WITH ACES II SEAT
TRANSFER FUNCTION ANALYSIS OF Z AXIS HEAD ACCELERATION

	NATURAL FREQUENCY (Hz)	DAMPING RATIO
CELL E	12.78 ± 0.30	0.1205 ± 0.0443
CELL F	12.97 ± 0.29	0.1343 ± 0.0383
CELL G	13.01 ± 0.30	0.1541 ± 0.0601
CELL H	12.60 ± 1.44	0.1847 ± 0.0742

CELL E: SEAT BACK ANGLE +5° CELL G: SEAT BACK ANGLE -5°
CELL F: SEAT BACK ANGLE 0° CELL H: SEAT BACK ANGLE -10°

TABLE 22
VARIABLE SEAT BACK ANGLE EVALUATION WITH ACES II SEAT
TRANSFER FUNCTION ANALYSIS OF Z AXIS HEAD ACCELERATION
WILCOXON PAIRED-REPLICATE RANK TEST (TWO-TAILED)

MATCHED PAIRS	NATURAL FREQUENCY (Hz)	DAMPING RATIO
E - F	I 98%	I
E - G	I 99%	I 95%
E - H	I 95%	I 99%
F - G	I	I
F - H	I	I 95%
G - H	I	I

I INDICATES A TREND TO INCREASE FROM CELL TO CELL

CELL E: SEAT BACK ANGLE +5° CELL G: SEAT BACK ANGLE -5°
CELL F: SEAT BACK ANGLE 0° CELL H: SEAT BACK ANGLE -10°

TABLE 23
VARIABLE SEAT BACK ANGLE EVALUATION WITH ACES II SEAT
TIME DOMAIN ANALYSIS OF Z AXIS HEAD ACCELERATION

	NATURAL FREQUENCY (Hz)	DAMPING RATIO
CELL E	11.32 ± 1.57	0.124 ± 0.136
CELL F	11.90 ± 1.98	0.130 ± 0.123
CELL G	11.25 ± 1.71	0.183 ± 0.212
CELL H	11.55 ± 2.90	0.336 ± 0.393

CELL E: SEAT BACK ANGLE +5°
CELL F: SEAT BACK ANGLE 0°
CELL G: SEAT BACK ANGLE -5°
CELL H: SEAT BACK ANGLE -10°

TABLE 24
VARIABLE SEAT BACK ANGLE EVALUATION WITH ACES II SEAT
TIME DOMAIN ANALYSIS OF Z AXIS HEAD ACCELERATION
WILCOXON PAIRED-REPLICATE RANK TEST (TWO-TAILED)

MATCHED PAIRS	NATURAL FREQUENCY (Hz)	DAMPING RATIO
E - F	I	I
E - G	I	I
E - H	D	I 98%
F - G	D 95%	I
F - H	D	I 95%
G - H	D	I 95%

I INDICATES A TREND TO INCREASE; D INDICATES A TREND TO DECREASE

CELL E: SEAT BACK ANGLE +5°
CELL F: SETA BACK ANGLE 0°
CELL G: SEAT BACK ANGLE -5°
CELL H: SEAT BACK ANGLE -10°

MEDICAL FINDINGS

The following briefly describes the occurrence of an end-plate vertebral fracture in a test subject during a 10 G impact. The test subject was an active duty Air Force officer and member of the Impact Acceleration Stress Panel who had received his medical screening. The subject (all other subjects as well) was restrained by a PCU-15/P torso harness and lap belt. In this particular case, the seat-back angle was 5° aft of vertical.

Following the impact, the subject complained of "having the wind knocked out of him" and stated that during free-fall of the VDT carriage (prior to impact) he relaxed too much and was unable to regain proper impact position. Proper impact position is back against the seat-back and helmet held firmly against the headrest with tension sufficient to maintain a vertical alignment of the head and torso. It was noted that the test conductor observed the improper position of the subject's head and shoulders just prior to impact. On physical exam, the subject complained of mild back pain between the scapula but no pain over the vertebral column to palpation. Twenty-four hours later, the subject complained of mild right sided chest pain and further exams were required.

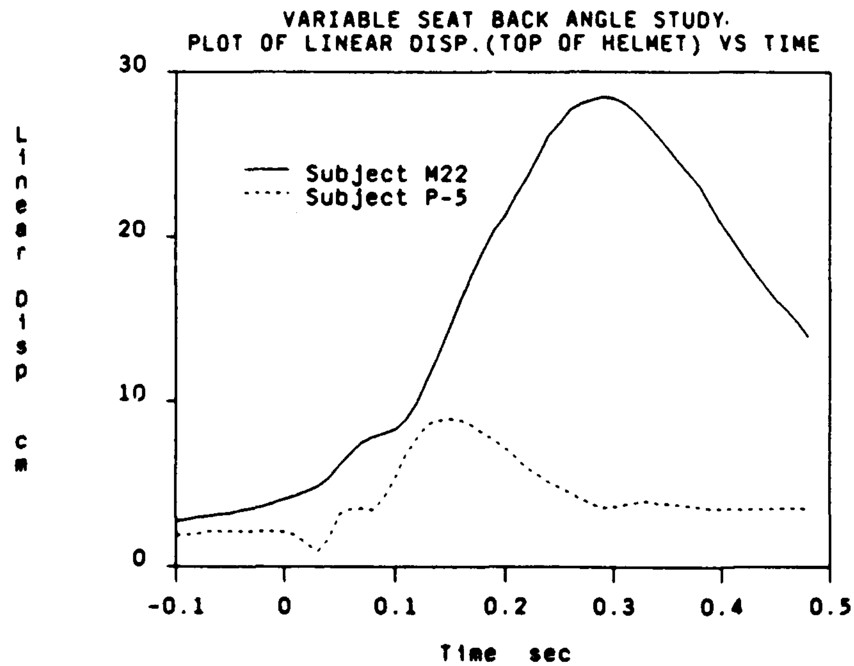
A diagnostic work up was begun which included: tomography, a bone scan, and Magnetic Resonance Imaging (MRI). The work-up revealed a fracture on the anterior edges of the fourth and fifth thoracic vertebrae with decreased anterior height. Although this subject weighed less than the other subjects, his height, sitting height, and mid-shoulder sitting height were not far from the mean of the other subjects participating in the program.

A review of the electronic data showed that he did not experience any increased linear head and chest accelerations compared to the other subjects in this experimental condition; however, he did experience a much higher angular acceleration (approximately 2.5X) and the head displacement data shows that the subject's head was displaced forward more than the other subjects at the start, peak, and end of the impact pulse. Table 25 provides a review of the electronic data as well as the head displacement data. Figure 10 also provides a comparison of the linear displacement of the top of the subject's head as a function of time versus another subject who represents the average response of the rest of the subjects. It is quite apparent that the subject has lost control of his position by the end of the impact pulse as indicated by the severe displacement (hyperflexion) of his head.

In conclusion, the mechanism of injury for the mid-thoracic compression fracture was a combined axial (+Gz) loading and hyperflexion due to the forward head position of the subject at the time of impact. During impact, the subject was unable to gain control of his posture and head displacement continued until the completion of the impact. Lack of proper position and bracing was the contributing factor to increasing the risk to this subject and only emphasizes the continued need for strict guidance for the subjects during all phases of an impact test program.

TABLE 25
VARIABLE SEAT BACK ANGLE EVALUATION WITH ACES II SEAT
COMPARISON OF SUBJECT M22 DATA WITH AVERAGE CELL E DATA
ACCELERATION LEVEL 10G, +Z AXIS, PCU-15/P RESTRAINT HARNESS

PARAMETER	SUBJECT M22	CELL E (ANGLE 5°)
CHEST X ACCELERATION (G)	0.88	4.60 ± 1.69
CHEST Z ACCELERATION (G)	15.30	15.68 ± 1.69
RESULTANT CHEST ACCELERATION (G)	15.32	16.32 ± 1.56
CHEST Ry ACCELERATION (rad/s²)	-198.67	-252.08 ± 130.47
HEAD X ACCELERATION (G)	1.44	2.69 ± 1.29
HEAD Z ACCELERATION (G)	12.91	13.67 ± 1.40
RESULTANT HEAD ACCELERATION (G)	12.99	14.02 ± 1.32
HEAD Ry ACCELERATION (rad/s²)	-737.09	-257.38 ± 124.99
RESULTANT SHOULDER LOAD (lb)	234.76	173.57 ± 58.46
RESULTANT SEAT FORCE (lb) (NORMALIZED BY SUBJECT WEIGHT)	14.86	15.11 ± 1.15
DISPLACEMENT (cm) AT TIME:		
t = 0	3.92	1.84 ± 2.67
t = 87	8.02	2.95 ± 4.95
t = 220	22.58	-0.77 ± 6.76



CONCLUSIONS

The analysis of data from this test program indicates that the human dynamic response to impact is affected by off-axis acceleration vectors.

As the body is positioned from aft of vertical to forward of vertical, it is expected that the force components of the shoulder loads in the x-axis direction increase and those in the z-axis direction decrease. This agrees with the collected data. Also, the data indicates that the resultant shoulder-strap force vector increases as the body position is changed from aft of vertical to forward of vertical which implies that the rate of z-axis decrease and x-axis increase are not equal.

The -x axis component of the head acceleration increased and the +x axis component of the head acceleration decreased as the seat back angle changed from aft of vertical to forward of vertical. This finding suggests an increase in the incidence of forward translation and downward rotation with forward rotation of the seat back angle. This is in agreement with the photo analysis which showed an increase in the forward translation and downward rotation and forward translation only of the head as the initial body position was moved from vertical to forward of vertical. This also agrees with the angular head acceleration data for seat back angles forward of vertical compared to vertical. Forward and downward rotation of the head are directly related to cervical spine flexion. These increases show that the cervical spine flexion tends to increase as the seat back angle is moved forward of vertical. The data for angular head acceleration comparisons aft of vertical to those vertical and forward of vertical shows a decrease in this parameter. This can be explained by noting that rearward rotation occurs when the seat back angle is aft of vertical as is evidenced by the head motion analysis. Rearward rotation is indicated by a negative angular acceleration or by the increase in +x-axis acceleration as the seat is positioned from vertical to aft of vertical. In these comparisons, it was the magnitude of the angular acceleration that was compared; therefore, the magnitude of the negative angular acceleration occurring when the seat back angle is aft of vertical is greater than the magnitude of the angular acceleration occurring when the seat back angle is vertical or forward of vertical. Since rearward rotation and cervical spine extension are directly related, it can be seen that there is a trend for the incidence of cervical spine extension to increase when a seat back angle aft of vertical is used.

The results of the electronic data analysis and the subjective evaluation of the gross head movements of the subjects are further substantiated by the analysis of the digitized photogrammetric data. The digitization clarified the resultant displacement of the subject's heads and also validated the tendency of the head to increase in rotation or rotation and translation during impact as the seat-back angle changed from +5° to -10°.

The natural frequency and damping ratio of the head as a function of seat-back angle were assessed using two techniques. The frequency domain analysis indicated that the frequency response of the subject's head varied as a function of the seat-back angle, but the time domain analysis indicated that the frequency response of the head was not affected by the change in the seat-back angle. This analysis is very important because it determines whether the frequency response of the head needs to be taken into account during analytical studies of the human biodynamic response to various ejection profiles that include variable seat backs.

The resultant seat load forces tend to increase as the seat back angle is changed from aft of vertical to forward of vertical. This would seem to indicate that the compressive and shear forces on the spine increase as the seat is moved through this range of angles; however, the data only indicated trends and were not statistically significant.

To assess injury potential caused by variances in seat back angle, additional testing must be conducted to collect data to determine the extent of these increases of compressive and shear forces, and cervical spine flexion and extension. Additional work must also be conducted to investigate the two different frequency response techniques, determine why they provided different results, and possibly see if another technique could be used.

REFERENCES

1. Baumann, R.C., Brinkley, J.W. and Brandau, A.G., Back Injuries Experienced During Ejection Seat Testing. Presented at the 39th Annual Aerospace Medical Association Meeting, 1968.

2. Brinkley, J.W., Dynamic Evaluation of the F-4 Ejection Seat. Summary of Findings, Aerospace Medical Research Laboratory, Memorandum, Wright-Patterson AFB, Ohio, 1967.

3. Brinkley, J.W., Dearing, E. and Rauterkus, L. Evaluation of the Effects of Selected Egress System Design Parameters During $+G_z$ Acceleration, AMRL-TR-69-51, 1969.

4. Brinkley, J.W. and Shaffer, J.T. Dynamic Simulation Techniques for the Design of Escape Systems: Current Applications and Future Air Force Requirements, AMRL-TR-71-29, 1971.

5. Brinkley, J.W., Raddin, J.H. Jr., Hearon, B.F., McGowan, L.A. and Powers, J.M. Evaluation of a Proposed, Modified F/FB-111 Crew Seat and Restraint System, AFAMRL-TR-80-52, 1981.

6. Brinkley, J.W., Hearon, B.F., Raddin, J.H. Jr., McGowan, L.A. and Powers, J.M. Vertical Impact Tests of a Modified F/FB-111 Crew Seat to Evaluate Headrest Position and Restraint Configuration Effects, AFAMRL-TR-82-51, 1982.

7. Brown, W.K., Rothstein, J.D. and Foster, P. Human Response to predicted Apollo Landing Impacts in Selected Body Orientations. Aerospace Medicine, April 1966.

8. Clarke, N.R., Managan, R.F., Weis, E.B. Jr., Brinkley, J.W. and Temple, W.E. Human Response to Touchdown Impact on the Apollo Lunar Excursion Module, Aerospace Medical Research Laboratory, Memorandum, Wright-Patterson AFB, Ohio, 1963.

9. Hearon, B.F., Brinkley, J.W., Hudson, D.M. and Saylor, W.J. Effects of a Negative G Strap on Restraint Dynamics and Human Impact Response, AFAMRL-TR-83-083, 1983.

10. Hearon, B.F. and Brinkley, J.W. Effect of Seat Cushions on Human Response to $+G_z$ Impact. Aviation, Space and Environmental Medicine, 57:113-121.

11. Military Specification, Webbing, Textile, Polyester, Low Elongation, MIL-W-25361C, 10 October 1974.

12. Staff of Anthropology Research Project, July 1978, Anthropometric Source Book, Volume 1: Anthropometry for Designers NASA Reference Publication 1024, National Aeronautics and Space Admininstration, Lyndon B. Johnson Space Center, Houston, Texas.

13. Walpole, R.E. and Myers, R.H. Probability and Statistics for Engineers and Scientists. New York, NY: Macmillan Publishing Company, 1985.

14. Wilcoxon, F. and Wilcox, R.A. Some Rapid Approximate Statistical Procedures. Lederle Laboratories, New York, 1964.

TEST CONFIGURATION AND
DATA ACQUISITION SYSTEM FOR THE
EFFECTS OF SEAT CUSHIONS AND SEAT BACK
ANGLE ON HUMAN RESPONSE DURING +Gz
IMPACT ACCELERATION
TEST PROGRAM

Prepared under
Contract F33615-86-C-0531
November 1986

Prepared by
DynCorp (formerly Dynalectron Corporation)
AAMRL Division
Building 824, Area B
Wright-Patterson AFB, Ohio 45433

TABLE OF CONTENTS

PAGE

INTRODUCTION.. 32

1. TEST FACILITY.. 32
2. SEAT FIXTURE... 32
3. INSTRUMENTATION.. 32
   3.1 ACCELEROMETERS... 34
   3.2 LOAD TRANSDUCERS... 35
   3.3 CALIBRATION.. 36
4. DATA ACQUISITION... 37
   4.1 AUTOMATIC DATA ACQUISITION AND CONTROL SYSTEM................... 37
   4.2 PHOTOGRAMMETRIC DATA ACQUISITION............................... 38
5. PROGRAM OPERATION
   5.1 INTRODUCTION... 38
   5.2 PROGRAM OPERATION.. 39
   5.3 FLOWCHART INFORMATION.. 39

LIST OF TABLES

TABLE PAGE

A-1. INSTRUMENTATION REQUIREMENTS
   A-1a. PAGE 1 OF 3..40
   A-2b. PAGE 2 OF 3..41
   A-3c. PAGE 3 OF 3..42
A-2. TRANSDUCER PRE- AND POST-CALIBRATION
   A-2a. PAGE 1 OF 4..43
   A-2b. PAGE 2 OF 4..44
   A-2c. PAGE 3 OF 4..45
   A-2d. PAGE 4 OF 4..46

LIST OF ILLUSTRATIONS

FIGURE PAGE

A-1. VERTICAL DECELERATION TOWER...................................47
A-2. VIP SEAT POSITIONS... 48
A-3. AAMRL/BBP COORDINATE SYSTEM.................................... 33
A-4. LOAD TRANSDUCER LOCATIONS...................................... 49
A-5. LOAD LINK INSTRUMENTATION...................................... 35
A-6. ADACS INSTALLATION... 50

CONT'D - LIST OF ILLUSTRATIONS

FIGURE PAGE

A-7. AUTOMATIC DATA ACQUISITION AND CONTROL SYSTEM............. 51
A-8. DATA ACQUISITION AND STORAGE SYSTEM BLOCK DIAGRAM......... 52
A-9. ONBOARD CAMERA LOCATIONS................................... 53
A-10. FIDUCIAL TARGET LOCATIONS................................. 54
A-11. AUTOMATIC FILM READER..................................... 55
A-12. PROGRAM FLOWCHARTS FOR VSVDØA
A-12a. PAGE 1 OF 2.. 56
A-12b. PAGE 2 OF 2.. 57
A-13. PROGRAM FLOWCHART FOR VSVDØB............................... 58
A-14. PROGRAM FLOWCHARTS FOR VSVDØC
A-14a. PAGE 1 OF 2.. 59
A-14b. PAGE 2 OF 2.. 60
A-15. PROGRAM FLOWCHART FOR VSVDØD............................... 61
A-16. PROGRAM FLOWCHART FOR VSVDØE............................... 62

INTRODUCTION

This report was prepared by DynCorp (formerly Dynalectron Corporation) for the Harry G. Armstrong Aerospace Medical Research Laboratory (AAMRL/BBP) under Air Force Contract F33615-86-C-0531.

The information provided herein describes the test facility, test fixture, data acquisition, instrumentation procedures and and the test configuration that were used in "The Effects of Seat Cushions and Seat Back Angle on Human Response During +Gz Impact Acceleration Test Program." The testing was done on the Vertical Deceleration Tower starting July 1986 and ending August 1986.

1. TEST FACILITY

The AAMRL Vertical Deceleration Tower, as shown in Figure A-1, was used for all of the tests.

The facility consists of a 60 ft. vertical steel tower which supports a guide rail system, an impact carriage supporting a plunger, a hydraulic deceleration device and a test control and safety system. The impact carriage can be raised to a maximum height of 42 ft. prior to release. After release, the carriage free falls until the plunger, attached to the undercarriage, enters a water filled cylinder mounted at the base of the tower. The deceleration profile produced as the plunger displaces the water in the cylinder is determined by the free fall distance, the carriage and test specimen mass, the shape of the plunger and the size of the cylinder orifice. For these tests, plunger number 102 was mounted under the carriage. Drop height varied depending on the test cell requirements which ranged from 5'6" to 8'3".

2. SEAT FIXTURE

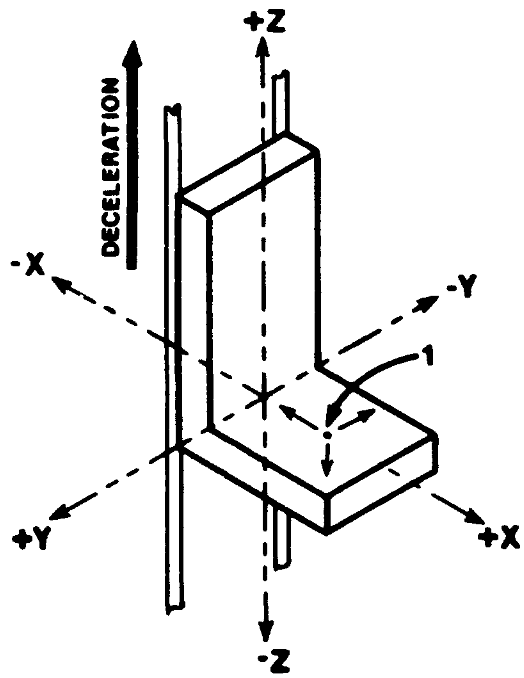
The VIP seat fixture, as shown in Figure A-1, was used for all of the tests. The seat was designed to withstand vertical impact acceleration up to 50 Gs. Its adjustable seat back allowed the subject to sit in one of four positions, as shown in Figure A-2. When positioned in the seat, the subject's upper legs were bent 90 degrees outward to a horizontal position with his lower legs bent 90 degrees downward to a vertical position. The subject was secured in the seat with a lap belt and shoulder strap. The lap belt and shoulder strap were preloaded to 20± lbs. as required in the test plan.

3. INSTRUMENTATION

The electronic data collected during this test program is described in Sections 3.1 and 3.2. Section 3.1 discusses accelerometers while Section 3.2 discusses load transducers. Section 3.3 discusses the calibration procedures that were used. The measurement instrumentation used in this test program is listed in Tables A-1a through A-1c. These tables designate the manufacturer, type, serial number, sensitivity and other pertinent data on each transducer used.

Accelerometers and load transducers were chosen to provide the optimum resolution over the expected test load range. Full scale data ranges were chosen to provide the expected full scale range plus 50% to assure the capture of peak signals. All transducer bridges were balanced for zero output except for those accelerometers in line with the force of gravity which were adjusted for plus 1 G. The accelerometer and load transducer coordinate system is shown in Figure A-3.

The accelerometers were wired to provide a positive output voltage when accelerations were applied in the +x, +y and +z directions, as shown in Figure A-3.



1. Typical fixed load cell and load link mounting point. Direction of arrows indicate direction of force applied to produce a positive output.

NOTE: Accelerometers were wired to produce a positive output voltage when accelerations were applied in the +x, +y and +z directions as shown.

FIGURE A-3: AAMRL/BBP COORDINATE SYSTEM

The load transducers included three types of load measurement devices. All were wired as follows:

> Fixed Load Cells - were wired to provide a positive output when force is applied in the indicated direction (Figure A-3).
>
> Triaxial Load Cells - were wired to provide a positive output when the belt was pulled towards the center of the seat.
>
> Load Links - were wired to provide a positive output when force is applied in the direction indicated (Figure A-3).

Carriage velocity was measured using a Globe Industries tachometer Model 22A672-2. The rotor of the tachometer was attached to an aluminum wheel with a rubber "O" ring around its circumference to assure good rail contact. The wheel contacted the track rail and rotated as the carriage moved, producing an output voltage proportional to the velocity.

3.1 Accelerometers

This section describes the accelerometer instrumentation as required in the AAMRL/BBP test plan.

Head accelerations were measured using three Endevco Model 2264-200 linear accelerometers and one Endevco Model 7302A angular (Ry) accelerometer. The accelerometers were mounted to the external edge of a plastic dental bite block. Each subject had his own set of custom fitted dental inserts that were used to support the bite block in his mouth. An aluminum tube extended from the bite block and located a fiducial target used for photo tracking purposes.

The chest accelerometer package consisted of three Endevco Model 2264-150 linear accelerometers mounted to a 1/2 x 1/2 x 1/2 inch aluminum block. An Endevco Model 7302A angular (Ry) accelerometer was mounted on a bracket adjacent to the triaxial chest block. The accelerometer packages were inserted into a steel protection shield to which a length of Velcro fastener strap was attached. The package was placed over the subject's sternum at the level of the xiphoid and was held there by fastening the Velcro strap around the subject's chest.

Carriage accelerations were measured using three Endevco accelerometers: Model 2262A-200 for the z direction, Model 2264-200 for the x direction and Model 7264-200 for the y direction. The three accelerometers were mounted on a small acrylic block and located behind the seat on the VIP seat structure.

Seat accelerations were measured using three Endevco accelerometers: one Model 2264-150 for accelerations in the x direction and two Model 2264-200s for accelerations in the y and z directions. Seat angular (Ry) acceleration was measured using an Endevco Model 7302B angular accelerometer. The three linear accelerometers were attached to a 1 x 1 x 3/4 inch acrylic block and were mounted below the seat near the back edge of the support frame. The angular accelerometer was attached to an aluminum bracket and was mounted near the center and below the seat.

Head accelerations for dummy tests were measured using three Endevco Model 2264-200 linear accelerometers and one Endevco Model 7302 angular accelerometer. These accelerometers were internally mounted in the head of the VIP 95 manikin.

3.2 Load transducers
This section describes the load transducer instrumentation as required in the AAMRL/BBP test plan.

The load transducer locations and dimensions are shown in Figure A-4.

Right lap, left lap and shoulder strap loads were each measured using GM3D-SW triaxial load cells, each capable of measuring loads in the x, y and z directions. The shoulder strap triaxial package was mounted on the seat frame between the seat back support plate and the headrest. The right and left lap triaxial packages were located on separate plates mounted on the side of the seat frame parallel to the seat pan.

Seat pan loads were measured using three load cells and three load links. The three load cells were Strainsert Model FL2.5U-2SPKT load cells. The three load links, as shown in Figure A-5, were fabricated by DynCorp using Micro Measurement Model EA-06-062TJ-350 strain gages. All six measurement devices were located under the seat pan support plate. The load links were used for measuring loads in the x and y directions, two in the x direction and one in the y direction. Each load link housed a swivel ball which acted as a coupler between the seat pan and load cell mounting plate. The Strainsert load cells were used for measuring loads in the z direction.

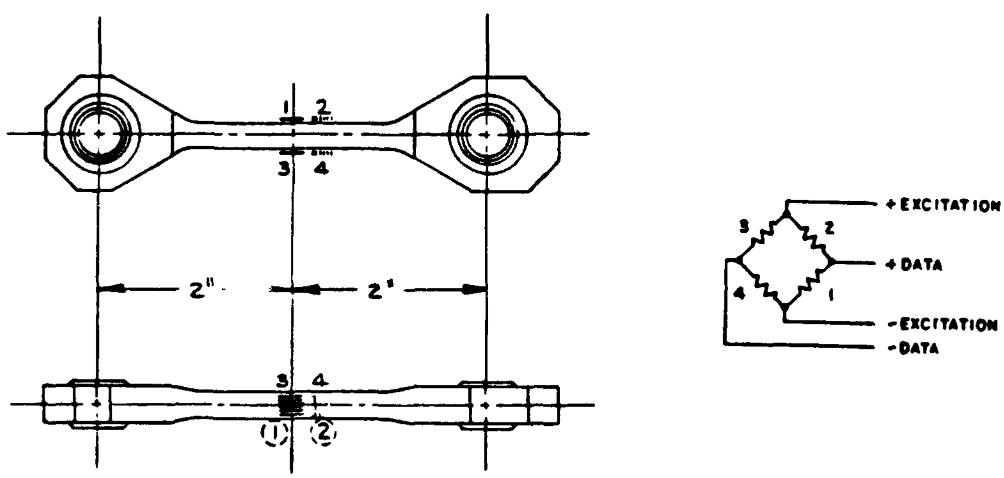


FIGURE A-5: LOAD LINK INSTRUMENTATION

3.3 Calibration

Calibrations were performed before and after testing to confirm the accuracy and functional characteristics of the transducers. Pre-program and post-program calibrations are given in Tables A-2a through A-2d.

The calibration of all Strainsert load cells was performed by the Precision Measurement Equipment Laboratories (PMEL) at Wright-Patterson Air Force Base. PMEL calibrated these devices on a periodic basis and provided current sensitivity and linearity data.

The calibration of the accelerometers was performed by DynCorp using the comparison method (Ensor, 1970). A laboratory standard accelerometer, calibrated on a yearly basis by Endevco with standards traceable to the National Bureau of Standards, and a test accelerometer were mounted on a shaker table. The frequency response and phase shift of the test accelerometer was determined by driving the shaker table with a random noise generator and analyzing the outputs of the accelerometers with a PDP 11/15 computer and 1923 Time Data Unit using Fourier analysis. The natural frequency and the damping factor of the test accelerometer were determined, recorded and compared to previous calibration data for that test accelerometer. Calibrations were made at 40 G and 100 Hertz. The sensitivity of the test accelerometer was determined by comparing its output to the output of the standard accelerometer.

The angular accelerometers were calibrated by DynCorp by comparing their output to the output of a linear standard accelerometer. The angular accelerometer is mounted parallel to the axis of rotation of a Honeywell low inertia D.C. motor. The standard accelerometer is mounted perpendicular to the axis of rotation at a radius of one inch to measure the tangential acceleration. The D.C. motor motion is driven at a constant sinusoidal angular acceleration of 100 Hertz and the sensitivity is calculated by comparing the rms output voltages of the angular and linear accelerometers.

The velocity wheel was calibrated by rotating the wheel at various revolutions per minute (RPM) and recording both the output voltage and the RPM. The sensitivity was dynamically checked with a G-HI measuring system and the Horizontal Accelerator Sled facility. This system consists of a timing unit and an optical sensor mounted near the track rails. As the sled traveled along the track rails, a metal blade on the sled interrupted the optical sensor beam. The timing unit displayed a time which was correlated to a velocity.

The load links and GM load cells were calibrated by DynCorp. These transducers were calibrated to a laboratory standard load cell in a special test fixture. The sensitivity and linearity of each test load cell were obtained by comparing the output of the test load cell to the output of the laboratory standard under identical loading conditions. The laboratory standard load cell, in turn, is calibrated by PMEL on a periodic basis.

4. DATA ACQUISITION

Data acquisition was controlled by a comparator on the Master Instrumentation Control Unit in the Instrumentation Station. The comparator was set to start data collection at a preselected time. A reference mark was electronically initiated to mark the electronic data and initiate a stobe light in the test area to mark the film frame for reference. The test was initiated when the countdown clock reached zero. The reference mark, used in the processing of data, was generated after T = Ø to place the reference mark close to the impact point.

Timing reference was provided by a master clock. Timing pulses of 100 pps were provided by the master clock to film data. The cameras were run at 500 frames per second and a timing pulse was placed on the film at 10 millisecond intervals.

Prior to each test and prior to placing the subject in the seat, data was acquired to establish a zero reference for all data sensors. This data was stored separately from the test data and was used in the processing of data.

4.1 Automatic Data Acquisition and Control System (ADACS)

Installation of the ADACS instrumentation is shown in Figure A-6. The three major components of the ADACS system are the power conditioner, signal conditioners and the encoder. A block diagram of the ADACS is shown in Figure A-7. The signal conditioners contain forty-eight module amplifiers with programmable amplifier gains and filters.

Bridge excitation for load cells and accelerometers was 10 VDC. Bridge completion and balance resistors were added as required to each module input connector.

The forty-eight module output data signals were digitized and encoded into forty-eight 11-bit digital words. Two additional 11-bit synchronization (sync) words were added to the data frame making a fifty word capability.

Three synchronization pulse trains (bit sync, word sync and frame sync) were added to the word frame and sent to the computer via a junction box data cable.

The PDP 11/34 mini-computer received serial data from the ADACS. The serial data coming from the carriage were converted to parallel data in the data formatter. The data formatter inputs data by direct memory access (DMA) into the computer memory via a buffered data channel where data were temporarily stored on disk and later transferred to magnetic tape for permanent storage. The interrelationships among the data acquisition and storage equipment are shown in Figure A-8.

Test data could be reviewed immediately after each test by using the "quick look" SCAN routine. SCAN was used to produce a plot of the data stored on any channel as a function of time. The routine determined the minimum and maximum values of any data plot. It was also used to calculate the rise time, pulse duration and carriage acceleration.

4.2 Photogrammetric Data Acquisition

Two onboard high-speed LOCAM cameras, operating at 500 frames per second, were used to produce the photogrammetric data. Each camera used a 9mm lens and were automatically started at a preset time in the test sequence by a signal from the camera and lighting control station. Both camera locations are shown in Figure A-9.

Motion of the subjects' head, shoulders and chest were quantified by tracking the motion of subject-mounted fiducials. Reference fiducials were placed on the test fixture. Two different sized fiducials were used, one being a .75" diameter black circle on a 1.25" diameter white target, the other a 1.25" diameter black circle on a 2.00" diameter white target. The locations of the fiducials generally followed the guidelines provided in "Film Analysis Guides for Dynamic Studies of Test Subjects, Recommended Practice" (SAE J138, March 1980). Fiducial target locations are identified in Figure A-10.

The photogrammetric data were time correlated in each test. Immediately prior to impact, an event signal triggered the flash unit to mark the camera film frame. At that time, a 100 PPS signal activated the camera L.E.D. driver which pulsed the camera L.E.D., producing a time mark at the film edge. This reference mark was then used to correlate the photogrammetric data with the electronically measured data.

The photogrammetric data will be processed as required on the Automatic Film Reader (AFR) system, shown in the block diagram in Figure A-11. The fiducial tracking routine is initiated via the Data General terminal. The tracking routine is booted from a floppy disk into the Nova 3/12 memory. The system is capable of tracking fiducials manually or automatically. The Nova 3/12 outputs an x-y film coordinate position to magnetic tape for each fiducial being tracked. Data are then transferred from magnetic tape to the DEC PCP 11/34 disk file for processing.

An Instant Analytical Replay (INSTAR) video system was also used to provide photogrammetric coverage of each test. This video recorder and display unit is capable of recording high-speed motion at a rate of 120 frames per second. Immediate replay of the impact is possible in real time or in slow motion.

5. PROGRAM OPERATION

5.1 Introduction

This section identifies the flowcharts and processing programs that were used for the VSBA Study conducted by the Biomechanical Protection Branch, Biodynamics and Bioengineering Division of the Harry G. Armstrong Aerospace Medical Research Laboratory.

The executable tasks for the VSBA Study processing programs are located on the Data Processing disk of the PDP 11/34. The test data is read into the computer using the DEC Peripheral Interchange Package from a digital magnetic tape with a density of 800 BPI and stored on an RLØ2 hard disk. All plots are output to a Tektronix hardcopy unit. The alphanumeric data itself is output to the Versatec line printer.

5.2 Program Operation

The five Fortran programs that process the VSBA Study test data are named "VSVDØA," "VSVDØB," "VSVDØC," "VSVDØD" and "VSVDØE." The command file which controls execution of these tasks is named "VSVD." The two characters "VS" identify the study (VSBA), the characters "VD" identify the facility (Vertical Deceleration Tower), "Ø" is the revision number and the last character determines the program order of execution.

Task A requires the user to enter the total number of tests to be processed and the zero and data filenames for each test. The user must then specify whether the default test parameters are to be used for processing. If the default parameters are selected, then the test number, subject identification, weight, age, height and sitting height are read in from the first block of the test data file. The cell type, nominal G level and left lap, right lap and shoulder preload values are also read in. If the default parameters are not selected, they must be entered by the user. Task A creates a command file containing execution commands for each test, which is called by command file "VSVD" after task A exits.

Task B creates the individual data files for each channel and data files for all sums, differences, products and resultants. Task C finds data maxima and minima for each channel, does any special processing required and outputs results to the data base. Task D outputs an alphanumeric cover sheet to the Versatec line printer/plotter based on the formats specified in the base and report format files. Task E plots the specified data channels for 600 ms after the reference mark and hardcopies the plots.

5.3 Program Flowcharts

Flowcharts of the five programs are shown in Figures A-12 through A-16. Each flowchart identifies the files used and the subroutines called by the program. Data channel numbers and accelerations or loads are listed where they occur in the analysis.

DIGITAL INSTRUMENTATION REQUIREMENTS

DYNALECTRON CORPORATION

THE EFFECTS OF

PROGRAM: SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz — DATE: 14 JUL 86 THRU 14 AUG 86

FACILITY: VERTICAL DECELERATOR TOWER — RUN: 1122 THRU 1214

DATA CHANNEL	DATA POINT	SENSOR MFG & TYPE	S/N	SENSOR SENS	EXCITE V	CHAN	FILTER MODEL	S/N	AMP GAIN	S/N	SAMPLE RATE	DECOM	F.S. SENS	FILTER HZ	SENSOR ZERO	RANGE	BRIDGE BALANCE RESISTORS	BRIDGE COMPLETION RESISTORS	SPECIAL NOTATIONS
1	Carriage Z	Endevco 2262A-200	FB42	4.20 mv/g	10.00	1	60	1	25	6	1K	1	23.8 g	120	2.5	+5.0 0.0	100K +in Gnd.	-	
2	Carriage X	Endevco 2264-200	BX17	2.792 mv/g	10.00	2	60	2	100	5	1K	1	8.95 g	120	2.5	+5.0 0.0	143K +in Gnd	1.50K	
3	Carriage Y	Endevco 7264-200	BH97R	2.767 mv/g	10.00	3	60	3	100	11	1K	1	9.04 g	120	2.5	+5.0 0.0	270K +in Gnd	"	
4	Head X	Endevco 2264-200	BP56	2.821 mv/g	10.00	4	60	4	50	3	1K	1	17.7 g	120	2.5	+5.0 0.0	-	1.65K	
5	Head Y	"	CF23	2.224 mv/g	10.00	5	60	5	50	2	1K	1	22.4 g	120	2.5	+5.0 0.0	130K +in Gnd	"	
6	Head Z	"	CR73	1.741 mv/g	10.00	6	60	6	25	9	1K	1	36.5 g	120	2.5	+5.0 0.0	165K +in Gnd	"	
7	Chest X	Endevco 2264-150	BC26	2.807 mv/g	10.00	7	60	7	50	15	1K	1	17.8 g	120	2.5	+5.0 0.0	1.2M -in Gnd	"	
8	Chest Y	"	B813	2.467 mv/g	10.00	8	60	8	100	30	1K	1	10.1 g	120	2.5	+5.0 0.0	220K +in Gnd	"	
9	Chest Z	"	2A20	2.648 mv/g	10.00	9	60	9	25	25	1K	1	37.8 g	120	2.5	+5.0 0.0	155K -in Gnd	"	
10	Left Seat Load	Strainsert FL2.5U-2SPKT	3294-1	8.02 uv/lb	10.00	10	60	10	201	1	1K	1	1551 LB	120	2.5	+5.0 0.0	-	-	
11	Right Seat Load	"	3294-2	8.03 uv/lb	10.00	11	60	11	201	14	1K	1	1549 LB	120	2.5	+5.0 0.0	-	-	
12	Center Seat Load	"	3294-4	8.08 uv/lb	10.00	12	60	12	100	34	1K	1	3094 LB	120	2.5	+5.0 0.0	-	-	
13	Left Load Link X	[illegible] EA-06-062 TJ-350	2	10.32 uv/lb	10.00	13	60	13	402	1	1K	1	603 LB	120	2.5	+5.0 0.0	140K +in Gnd	-	
14	Right Load Link X	"	3	10.35 uv/lb	10.00	14	60	14	402	6	1K	1	509 LB	120	2.5	+5.0 0.0	24K +in Gnd	-	

NO FACILITY IMPACT SWITCH REQUIRED.
COMPUTER SOFTWARE WILL DETERMINE THIS POINT
PER MR. BRINKLEY 14 JULY 86.

PAGE 1 OF 3

TABLE A-1a: INSTRUMENTATION REQUIREMENTS (PAGE 1 OF 3)

DIGITAL INSTRUMENTATION REQUIREMENTS

PROGRAM THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz DATE 14 JUL 86 THRU 16 AUG 86

FACILITY VERTICAL DECELERATOR TOWER RUN 1127 THRU 1214

DYNALECTRON CORPORATION

DATA CHANNEL	DATA POINT	XDUCER MFG & TYPE	S/N	XDUCER SENS	EXCITE V	CHAN	FILTER SERIES	FILTER S/N	AMP GAIN	AMP S/N	SAMPLE RATE	FORMAT	F.S. SENS	FILTER HZ	XDUCER ZERO	RANGE	BRIDGE BALANCE RESISTORS	BRIDGE COMPLETION RESISTORS	SPECIAL NOTATIONS
15	Left Lap Load X	GSE 30-3W	15X	5.36 uv/lb	10.00	15	60	15	402	7	1K	1	1160 LB	120	2.5	+5.0 0.0	5.2K +in Gnd	-	
16	Left Lap Load Y	"	15Y	5.35 uv/lb	10.00	16	60	16	800	2	1K	1	584 LB	120	2.5	+5.0 0.0	16K +in Gnd	-	
17	Left Lap Load Z	"	15Z	6.29 uv/lb	10.00	17	60	17	402	3	1K	1	989 LB	120	2.5	+5.0 0.0	4.9K +in Gnd	-	
18	Right Lap Load X	"	21X	5.07 uv/lb	10.00	18	60	18	402	5	1K	1	1227 LB	120	2.5	+5.0 0.0	8.2K +in Gnd	-	Test 1127-1210 Sens. @ 4.89 uv/lb, F. S. @ 1272 LB
19	Right Lap Load Y	"	21Y	4.85 uv/lb	10.00	19	60	19	800	3	1K	1	644 LB	120	2.5	+5.0 0.0	3.7K +in Gnd	-	Test 1127-1210 Sens. @ 4.82 uv/lb, F. S. 648 LB
20	Right Lap Load Z	"	21Z	6.08 uv/lb	10.00	20	60	20	402	2	1K	1	1023 LB	120	2.5	+5.0 0.0	47K +in Gnd	-	Test 1127-1210 Sens. @ 6.15 uv/lb, F. S. 1011 LB
21	Shoulder Load X	"	20Z	6.29 uv/lb	10.00	21	60	21	402	4	1K	1	989 LB	120	2.5	+5.0 0.0	48K -in Gnd	-	
22	Shoulder Load Y	"	20Y	5.78 uv/lb	10.00	22	60	22	800	4	1K	1	541 LB	120	2.5	+5.0 0.0	800K +in Gnd	-	
23	Shoulder Load Z	"	20X	5.57 uv/lb	10.00	23	60	23	402	8	1K	1	1117 LB	120	2.5	+5.0 0.0	30K +in Gnd	-	
25	Seat X Accel.	Endevco 2264-150	BB28	2.700 mv/g	10.00	25	60	25	50	5	1K	1	18.5 g	120	2.5	+5.0 0.0	72.4K +in Gnd	1.65K	
26	Seat Y Accel.	Endevco 2264-200	BV95	2.985 mv/g	10.00	26	60	26	50	12	1K	1	16.8 g	120	2.5	+5.0 0.0	-	1.47K	
27	Seat Z Accel.	"	BW07	2.812 mv/g	10.00	27	60	27	50	34	1K	1	17.8 g	120	2.5	+5.0 0.0	287K -in Gnd	-	
28	Center Load Link Y	MM/DYN EA-06-06 2TJ-350	5	9.91 uv/lb	10.00	28	60	28	402	10	1K	1	628 LB	120	2.5	+5.0 0.0	82K +in Gnd	-	
29	Vel. Tach.	Globe 22A672-2	4	.06209 V/F/S	-	29	30	1	1	-	1K	1	80.5	60	0.0	+5.0 0.0	-	-	Signal attenuated by 7.65 Sens.=.475 V/F/S ÷ 7.65=.06209 V/F/S @4.4" cir.

TEST 1145 - SEAT TRIAXIAL PACKAGE MOVED TO REAR OF SEAT FROM CENTER LOCATION PER MR. BRINKLEY.

PAGE 2 OF 3

TABLE A-1b: INSTRUMENTATION REQUIREMENTS (PAGE 2 OF 3)

DIGITAL INSTRUMENTATION REQUIREMENTS

PROGRAM THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DUR HC +Gz DATE 14 JUL 86 THRU 14 AUG 86

FACILITY VERTICAL DECELERATOR TOWER RUN 1127 THRU 1214

DYNALECTRON CORPORATION

DATA CHANNEL	DATA POINT	XDUCER MFG & TYPE	S/N	XDUCER SENS	EXCITE V	CHAN	FILTER SERIES	S/N	AMP GAIN	S/N	SAMPLE RATE	FORMAT	F.S. SENS	FILTER HZ	XDUCER ZERO	RANGE	BRIDGE BALANCE RESISTORS	BRIDGE COMPLETION RESISTORS	SPECIAL NOTATIONS
37	Event	-	-	-	-	37	1000	23	2.5	27	1K	1	5.0 Volt	2000	5.0	+5.0 0.0	-	-	
42	Head Ry Angular	Endevco 7302A	AB12	4.15uv/ RAD/SEC^2	10.00	42	60	42	201	17	1K	1	2997 RAD/SEC^2	120	2.5	+5.0 0.0	-	-	
43	Chest Ry Angular	"	AB15	6.60uv/ RAD/SEC^2	10.00	43	60	43	201	10	1K	1	1862 RAD/SEC^2	120	2.5	+5.0 0.0	440K -in Gnd	-	
44	Seat Ry Angular	7302B	PT47	3.65uv/ RAD/SEC^2	10.00	44	60	44	402	12	1K	1	1704 RAD/SEC^2	120	2.5	+5.0 0.0	-	-	
34	T = 0 Pulse	-	-	-	-	38	1000	11	1	-	1K	1	5.0 Volt	2000	0.0	+5.0 0.0	-	-	Used for computer processing
47	2.5 Volt Bias	-	-	-	-	47	100	7	1	-	1K	1	2.5 Volt	360	2.5	+5.0 0.0	-	-	
48	10 Volt Exc.	-	-	-	-	48	100	8	1	-	1K	1	2.5 Volt	360	2.5	+5.0 0.0	-	-	
30	Dummy Head X	Endevco 2264-200	CH74	2.906 mv/g	10.00	30	60	30	50	16	1K	1	17.2 g	120	2.5	+5.0 0.0	190K +in Gnd	1.65K	Dummy tests 1131 and subsequent
31	Dummy Head Y	"	BQ42	2.740 mv/g	10.00	31	60	31	50	23	1K	1	18.2 g	120	2.5	+5.0 0.0	220K +in Gnd	1.65K	Dummy tests 1131 and subsequent
32	Dummy Head Z	"	CH70	2.662 mv/g	10.00	32	60	32	25	29	1K	1	37.6	120	2.5	+5.0 0.0	80K +in Gnd	1.65K	Dummy tests 1131 and subsequent
33	Dummy Head Ang	Endevco 7302	A150	8.163uv/ RAD/SEC^2	10.00	33	60	33	100	15	1K	1	3063 RAD/SEC^2	120	2.5	+5.0 0.0	-	-	Dummy tests 1131 and subsequent

PAGE 3 OF 3

TABLE A-1c: INSTRUMENTATION REQUIREMENTS (PAGE 3 OF 3)

PROGRAM CALIBRATION LOG

PROGRAM: THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz **DATES:** 14 JUL 86 - 14 AUG 86

FACILITY: VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1127-1214

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% CHANGE	NOTES
			DATE	* SENS	DATE	* SENS		
CARRIAGE Z	ENDEVCO 2262A-200	FR42	7JUL86	4.20	20AUG86	4.189	-.3	* ALL SENS. IN mv/g
CARRIAGE X	ENDEVCO 2264-200	BX17	8JUL86	2.792	"	2.804	+.4	
CARRIAGE Y	ENDEVCO 7264-200	BH97H	9JUL86	2.767	"	2.783	+.6	
HEAD X	ENDEVCO 2264-200	BP56	28MAY86	2.821	14AUG86	2.839	+.6	
HEAD Y	"	CF23	"	2.224	"	2.257	+.4	
HEAD Z	"	CH73	"	2.741	"	2.751	+1.5	
CHEST X	ENDEVCO 2264-150	BC26	"	2.807	"	2.795	-.4	
CHEST Y	"	BB13	"	2.467	"	2.438	-1.2	
CHEST Z	"	2A20	"	2.648	"	2.633	-.6	
SEAT X	"	BB28	31DEC85	2.700	20AUG86	2.701	0	

SEPTEMBER 1985

PAGE 1 OF 4

TABLE A-2a: TRANSDUCER PRE- AND POST-CALIBRATION (1 OF 4)

PROGRAM CALIBRATION LOG

PROGRAM: THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz **DATES:** 14 JUL 86 - 14 AUG 86

FACILITY: VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1127-1214

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% CHANGE	NOTES
			DATE	* SENS	DATE	* SENS		
SEAT Y	ENDEVCO 2264-200	BV95	28MAY86	2.985	20AUG86	2.987	+.1	* ALL SENS. IN mv/g UNLESS
SEAT Z	"	BW07	9JAN86	2.812	"	2.820	+.3	NOTED OTHER-WISE.
DUMMY HEAD X	"	CH74	28MAY86	2.906	22AUG86	2.939	+1.1	
DUMMY HEAD Y	"	BQ42	"	2.740	"	2.740	0	
DUMMY HEAD Z	"	CH70	"	2.662	"	2.676	+.5	
DUMMY HEAD ANG.	ENDEVCO 7302	A150	29MAY86	8.163 uv/RAD/SEC^2	"	8.203 uv/RAD/SEC^2	+.5	
HEAD ANG.	ENDEVCO 7302A	AB12	28MAY86	4.15 uv/RAD/SEC^2	15AUG86	4.195 uv/RAD/SEC^2	+1.0	
SEAT ANG.	ENDEVCO 730[illegible]B	PT47	6JAN86	3.65 uv/RAD/SEC^2	22AUG86	3.732 uv/RAD/SEC^2	+2.2	
CHEST ANG.	ENDEVCO 7302A	AB15	29MAY86	6.68 uv/RAD/SEC^2	15AUG86	6.80 uv/RAD/SEC^2	+1.8	

SEPTEMBER 1985

PAGE 2 of 4

TABLE A-2b: TRANSDUCER PRE- AND POST-CALIBRATION (2 OF 4)

PROGRAM CALIBRATION LOG

PROGRAM: THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz **DATES:** 14 JUL 86 - 14 AUG 86

FACILITY: VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1127-1214

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% CHANGE	NOTES
			DATE	* SENS	DATE	* SENS		
LEFT LOAD LINK X	MM/DYN EA-06-062TJ-350	2	9JUL86	10.32	25AUG86	10.32	0	* NOTE - ALL SENS. IN uv/lb
RIGHT LOAD LINK X	"	3	"	10.55	"	10.66	+1.0	
CENTER LOAD LINK Y	"	5	"	9.91	"	9.94	+.3	
LEFT LAP LOAD X	GM 3D-SW	15X	"	5.36	"	5.41	+.9	
LEFT LAP LOAD Y	"	15Y	"	5.35	"	5.36	+.2	
LEFT LAP LOAD Z	"	15Z	"	6.29	"	6.30	+.2	
RIGHT LAP LOAD X	"	21X	"	5.07	"	5.08	+.2	
RIGHT LAP LOAD Y	"	21Y	"	4.85	"	4.84	-.2	
RIGHT LAP LOAD Z	"	21Z	"	6.08	"	6.07	-.2	
SHOULDER LOAD X	"	20Z	"	6.29	26AUG86	6.32	+.5	

SEPTEMBER 1985

PAGE 3 OF 4

TABLE A-2c: TRANSDUCER PRE- AND POST-CALIBRATION (3 OF 4)

PROGRAM CALIBRATION LOG

PROGRAM: THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz DATES: 14 JUL 86 - 14 AUG 86

FACILITY: VERTICAL DECELERATION TOWER RUN NUMBERS: 1127-1214

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% CHANGE	NOTES
			DATE	* SENS	DATE	* SENS		
SHOULDER LOAD Y	GM 3D-SW	20Y	9JUL86	5.78	26AUG86	5.78	0	* ALL SENS. IN uv/lb
SHOULDER LOAD Z	"	20X	"	5.57	"	5.61	+.7	

SEPTEMBER 1985

PAGE 4 OF 4

TABLE A-2d: TRANSDUCER PRE- AND POST-CALIBRATION (4 OF 4)

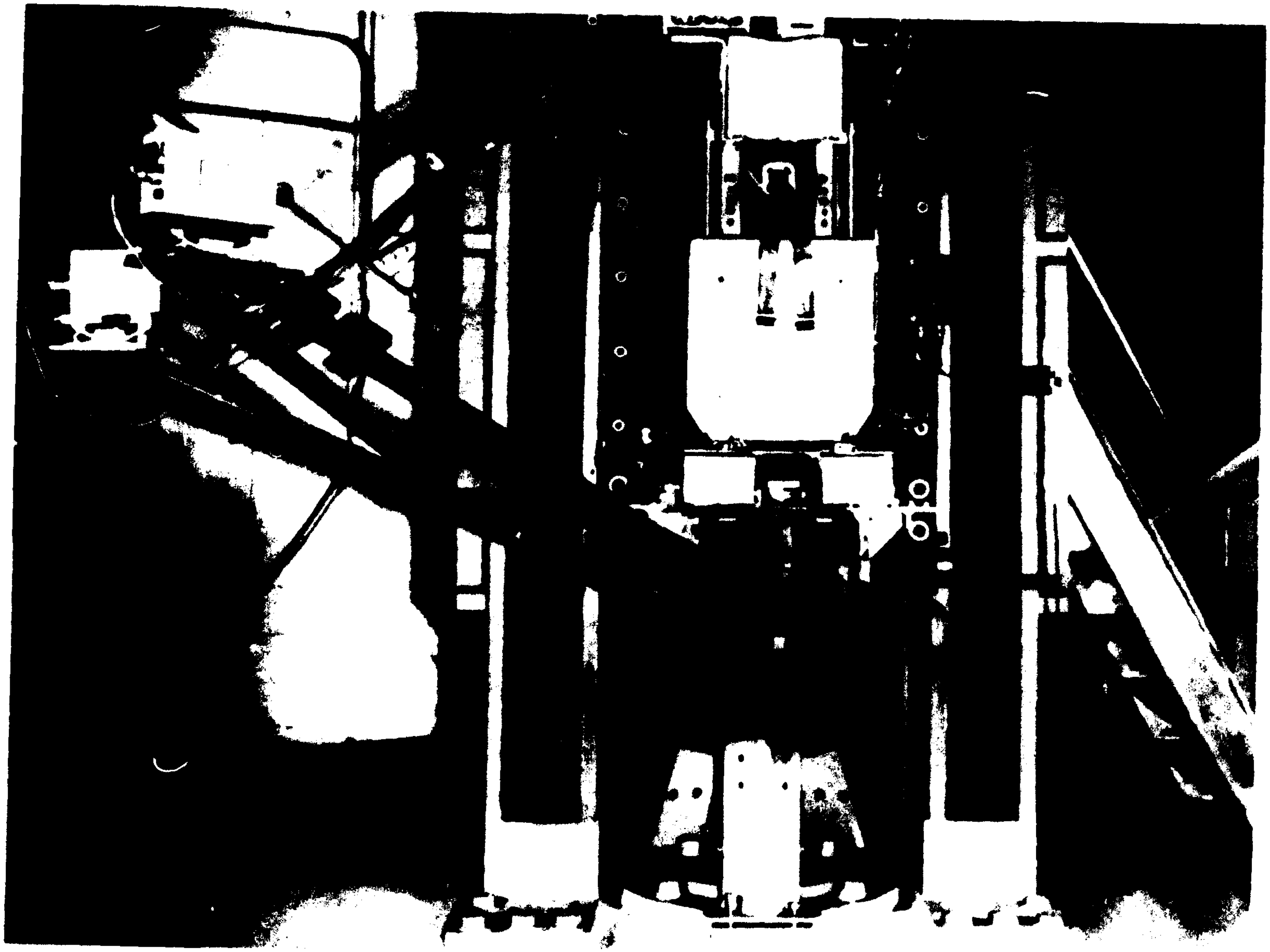
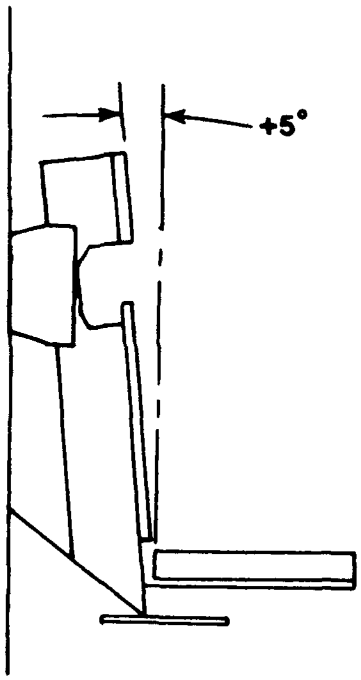
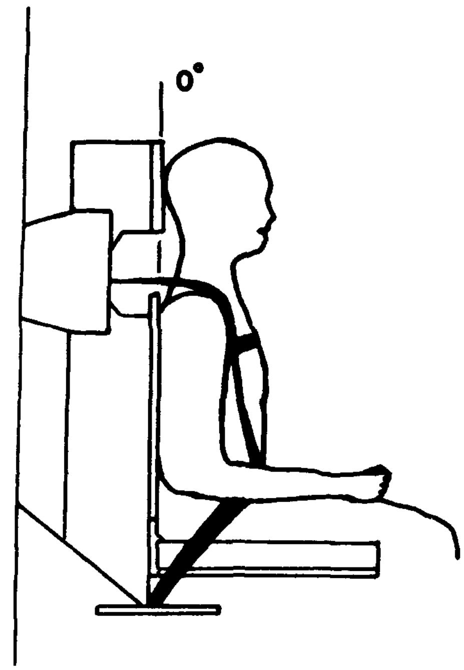


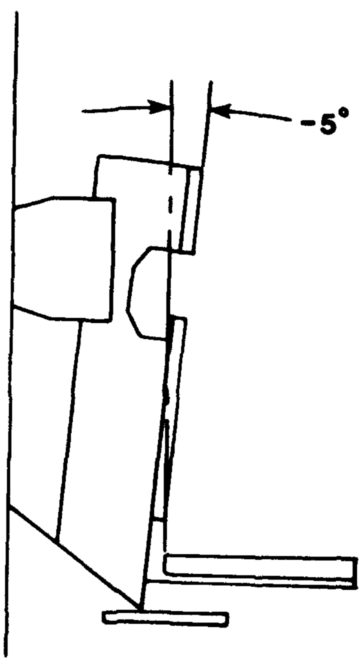
FIGURE A-1: VERTICAL DECELERATION TOWER



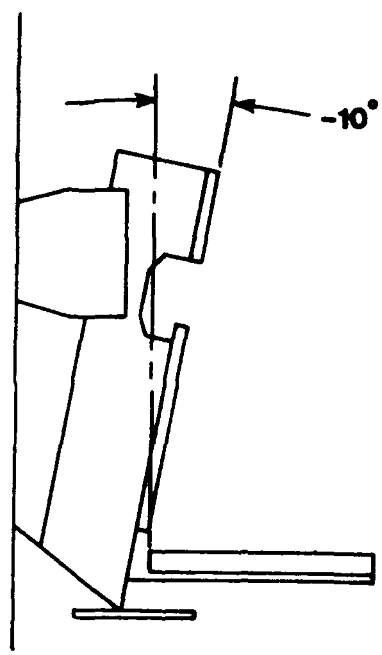
PLUS 5° SEAT



0° SEAT



MINUS 5° SEAT



MINUS 10° SEAT

FIGURE A-2: VIP SEAT POSITIONS

DESCRIPTION		DIMENSIONS IN CENTIMETERS		
		x	y	z
*1	SEAT REFERENCE POINT	0.00	0.00	0.00
2	CENTER SEAT LOAD	+11.75	0.00	-7.94
3	RIGHT SEAT LOAD	+40.64	+17.78	-7.94
4	LEFT SEAT LOAD	+40.64	-17.78	-7.94
5	LEFT LAP LOAD	-3.81	-22.86	-4.29
6	RIGHT LAP LOAD	-3.81	+22.86	-4.29
**7	SHOULDER STRAP LOAD	-14.67	0.00	+70.17
8	CENTER SEAT LINK	+17.78	+5.08	-9.45
9	RIGHT SEAT LINK	+20.32	+12.70	-9.45
10	LEFT SEAT LINK	+20.32	-12.70	-9.45

* All dimensions are referenced to the seat reference point (SRP). The seat reference point is located at the intersection of the horizontal seat plate (x axis) center line and the vertical back plate (z axis) center line.

** Dimensions shown are for the seat in the zero degree position. x and z measurements varied for each different seat position.

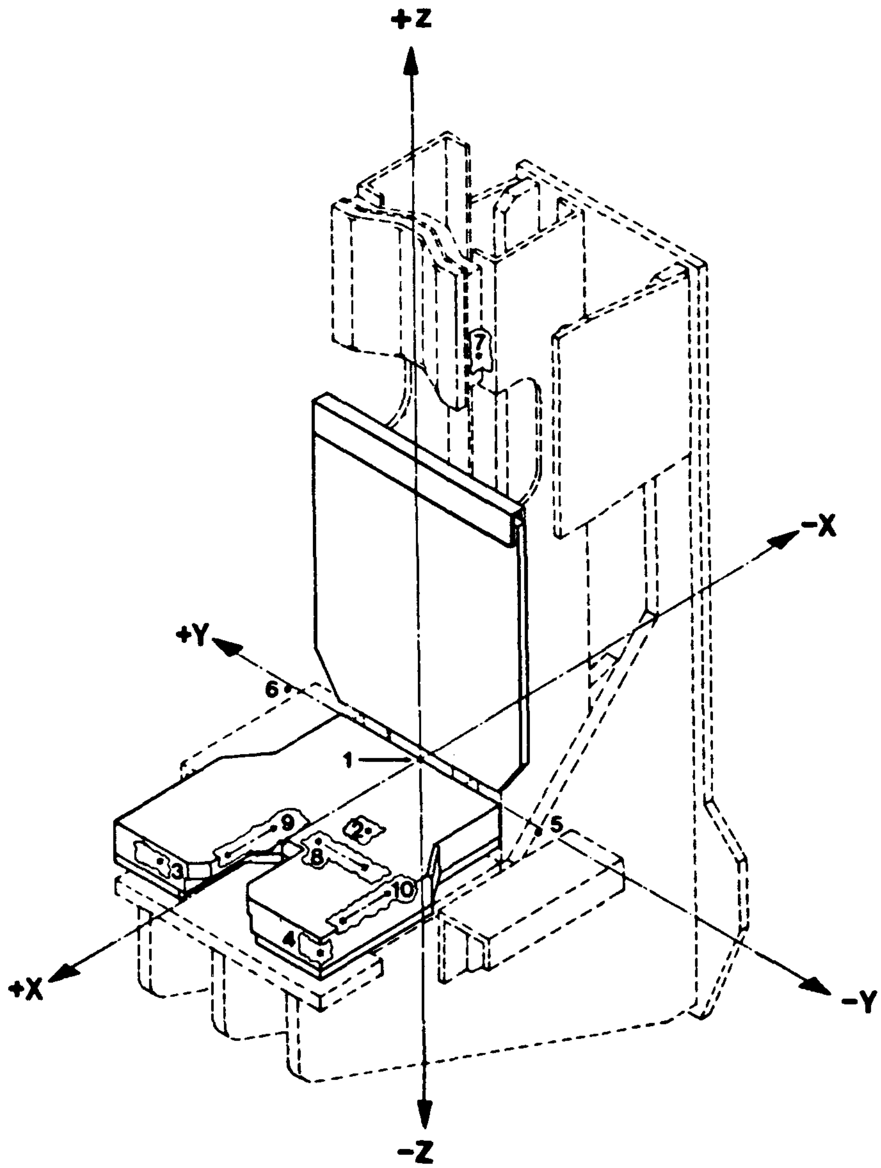


FIGURE A-4: LOAD TRANSDUCER LOCATIONS

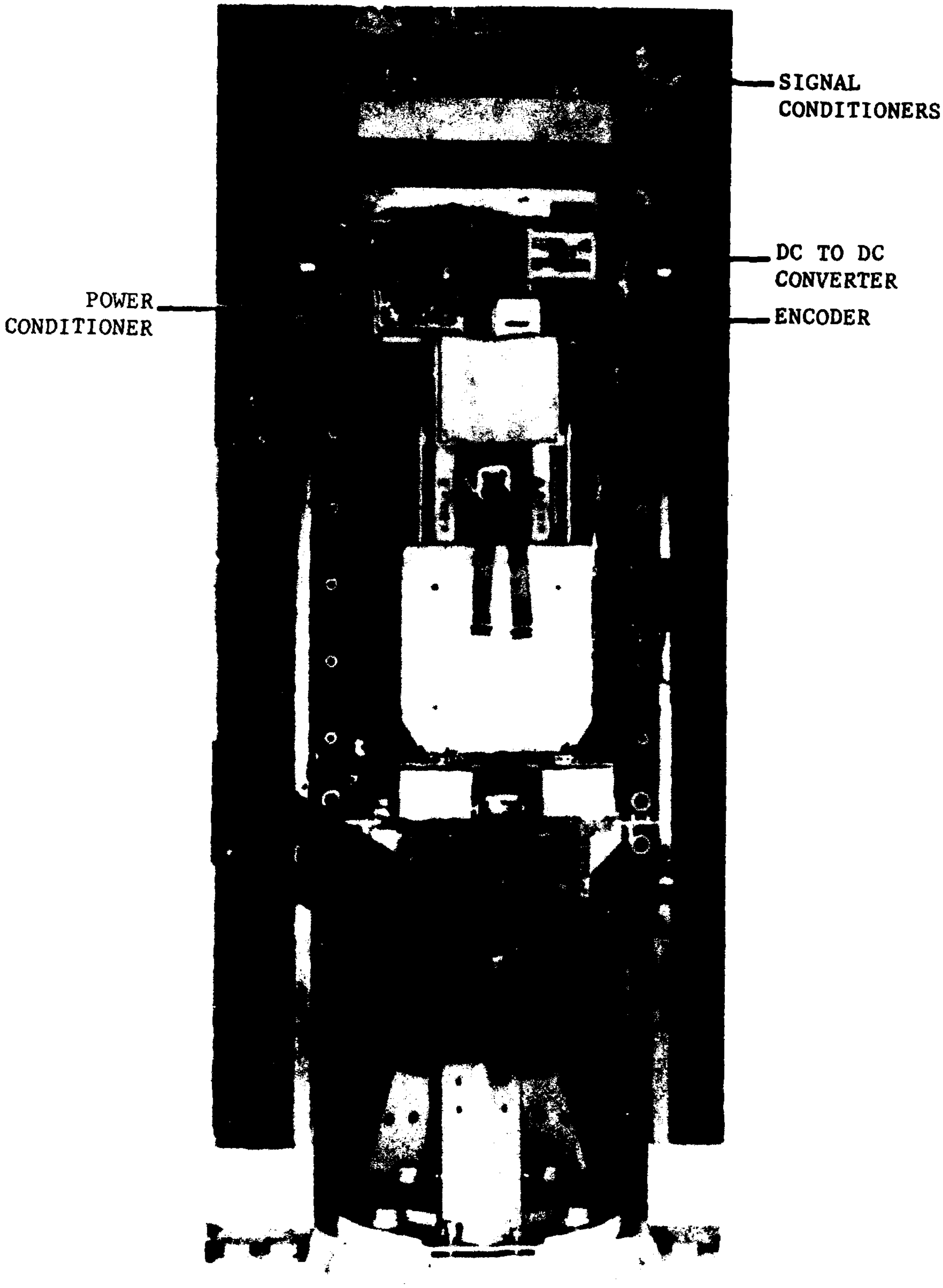
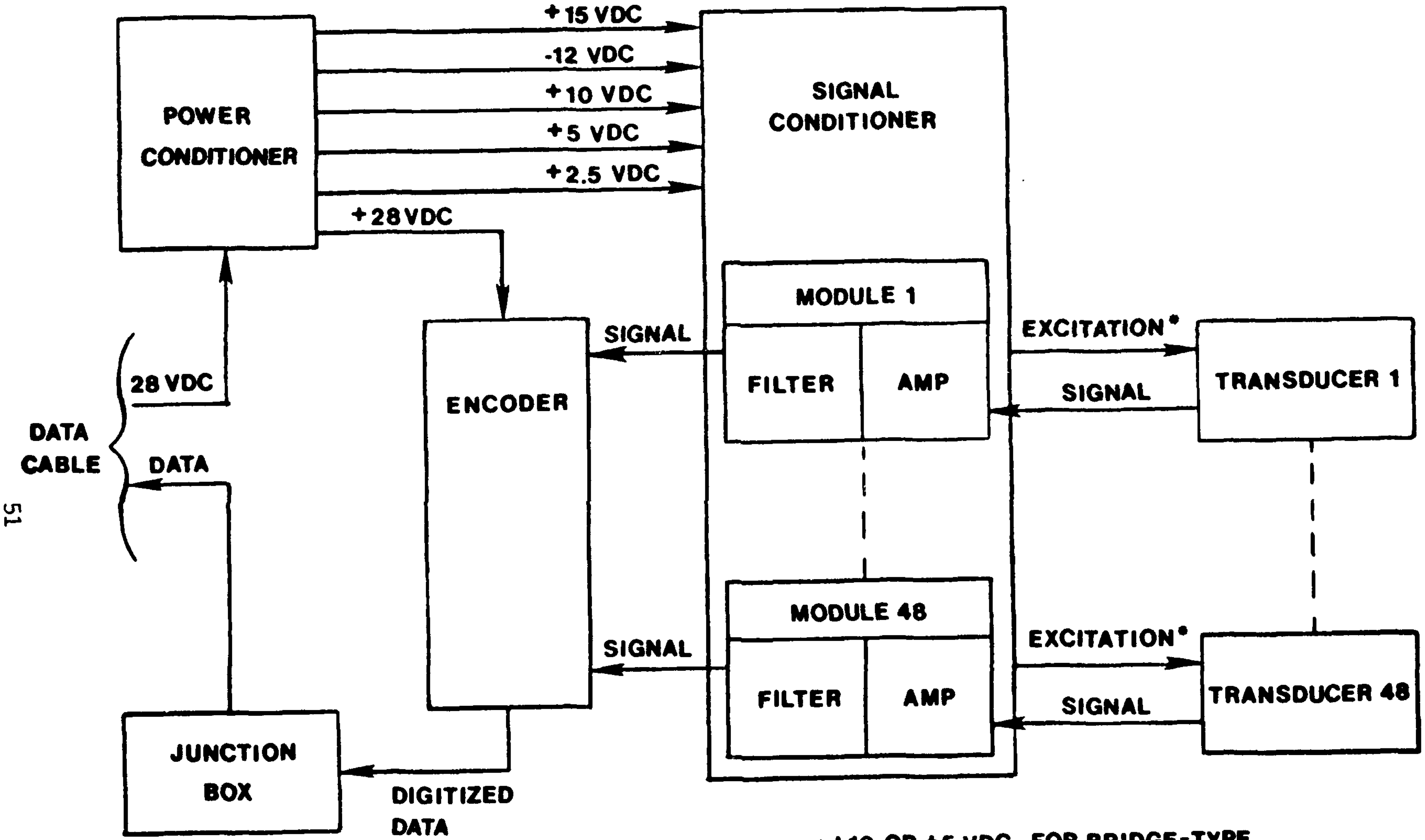


FIGURE A-6: ADACS INSTALLATION



* +10 OR +5 VDC, FOR BRIDGE-TYPE TRANSDUCERS ONLY.

FIGURE A-7: AUTOMATIC DATA ACQUISITION AND CONTROL SYSTEM

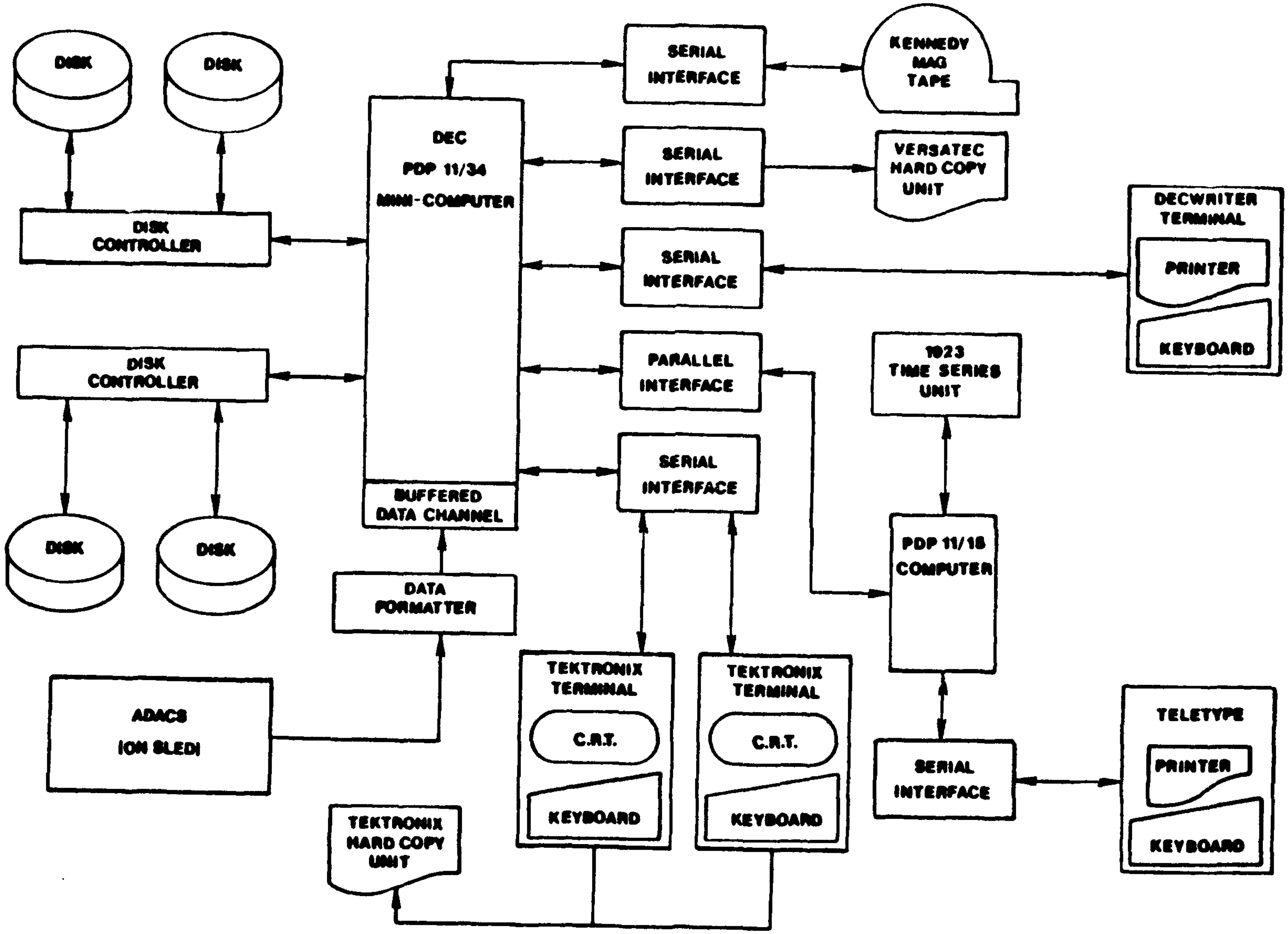


FIGURE A-8: DATA ACQUISITION AND STORAGE SYSTEM BLOCK DIAGRAM

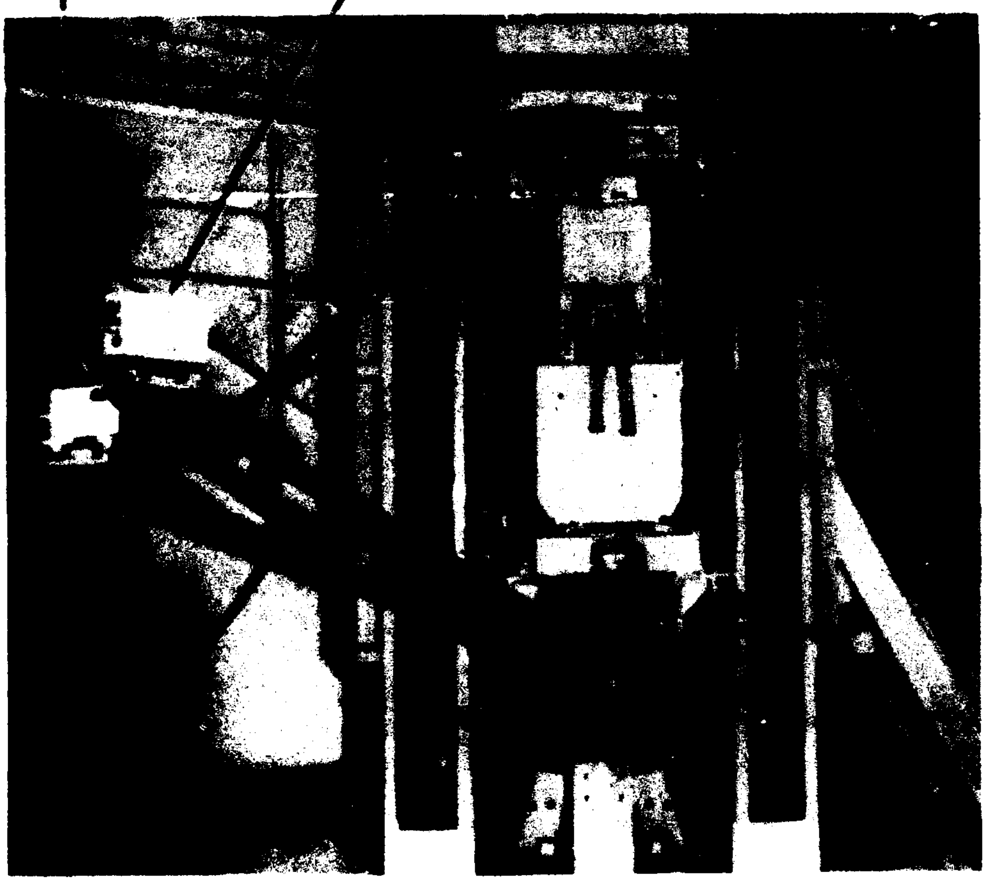
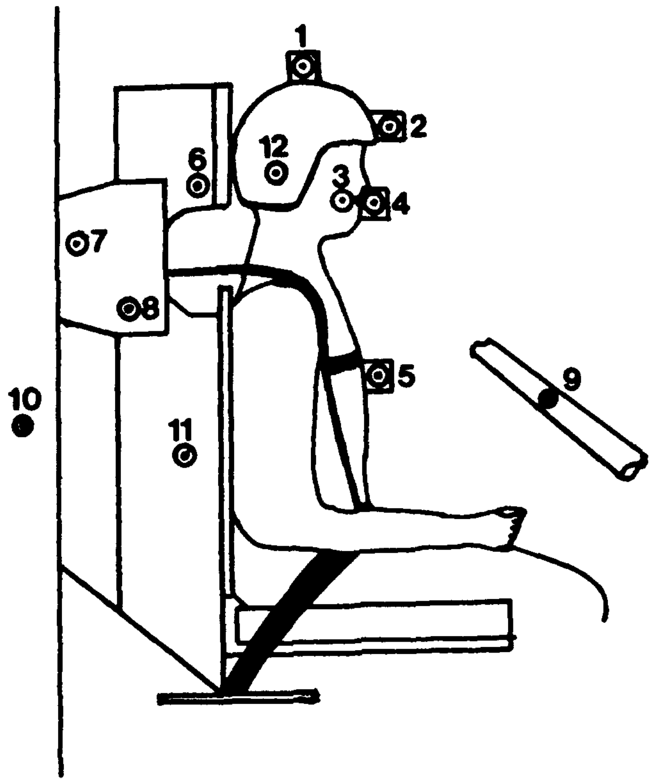


FIGURE A-9: ONBOARD CAMERA LOCATIONS



	DESCRIPTION	DIMENSIONS IN FEET x	y	z
1	UPPER HELMET	-	-	-
2	FRONTAL HELMET	-	-	-
3	CHEEK POINT	-	-	-
4	MOUTH PACK	-	-	-
5	CHEST PACK	-	-	-
* 6	HEAD REST	-0.2146	+0.5531	+2.7028
7	UPPER PLATE	-1.1780	+0.6846	+2.1052
* 8	LOWER PLATE	-0.6779	+0.6637	+1.8198
9	CAMERA STRUT	+1.7294	+2.3987	+2.2508
10	CARRIAGE	-1.3238	+0.6429	+0.9167
*11	SIDE RAIL	-0.5273	+0.5635	+0.9807
12	CENTER HELMET	-	-	-

* Fiducial target locations 6, 8 and 11 vary with respect to seat back angles. Below are x, y and z dimensions for seat back angles of +5, -5 and -10 degrees.

	DESCRIPTION	DIMENSIONS IN FEET x	y	z
	6 HEAD REST	-0.4465	+0.5531	+2.6823
$+5^{o}$	8 LOWER PLATE	-0.6693	+0.6663	+1.7813
	11 SIDE RAIL	-0.6099	+0.5635	+0.9318
	6 HEAD REST	+0.0230	+0.5531	+2.7161
-5^{o}	8 LOWER PLATE	-0.6726	+0.6689	+1.7729
	11 SIDE RAIL	-0.4423	+0.5635	+1.0214
	6 HEAD REST	+0.2618	+0.5531	+2.7036
-10^{o}	8 LOWER PLATE	-0.6654	+0.6689	+1.7969
	11 SIDE RAIL	-0.3580	+0.5635	+1.0531

All dimensions are referenced to the seat reference point (SRP). The seat reference point is located at the intersection of the horizontal seat plate (x axis) center line and the vertical back plate (z axis) center line.

FIGURE A-10: FIDUCIAL TARGET LOCATIONS

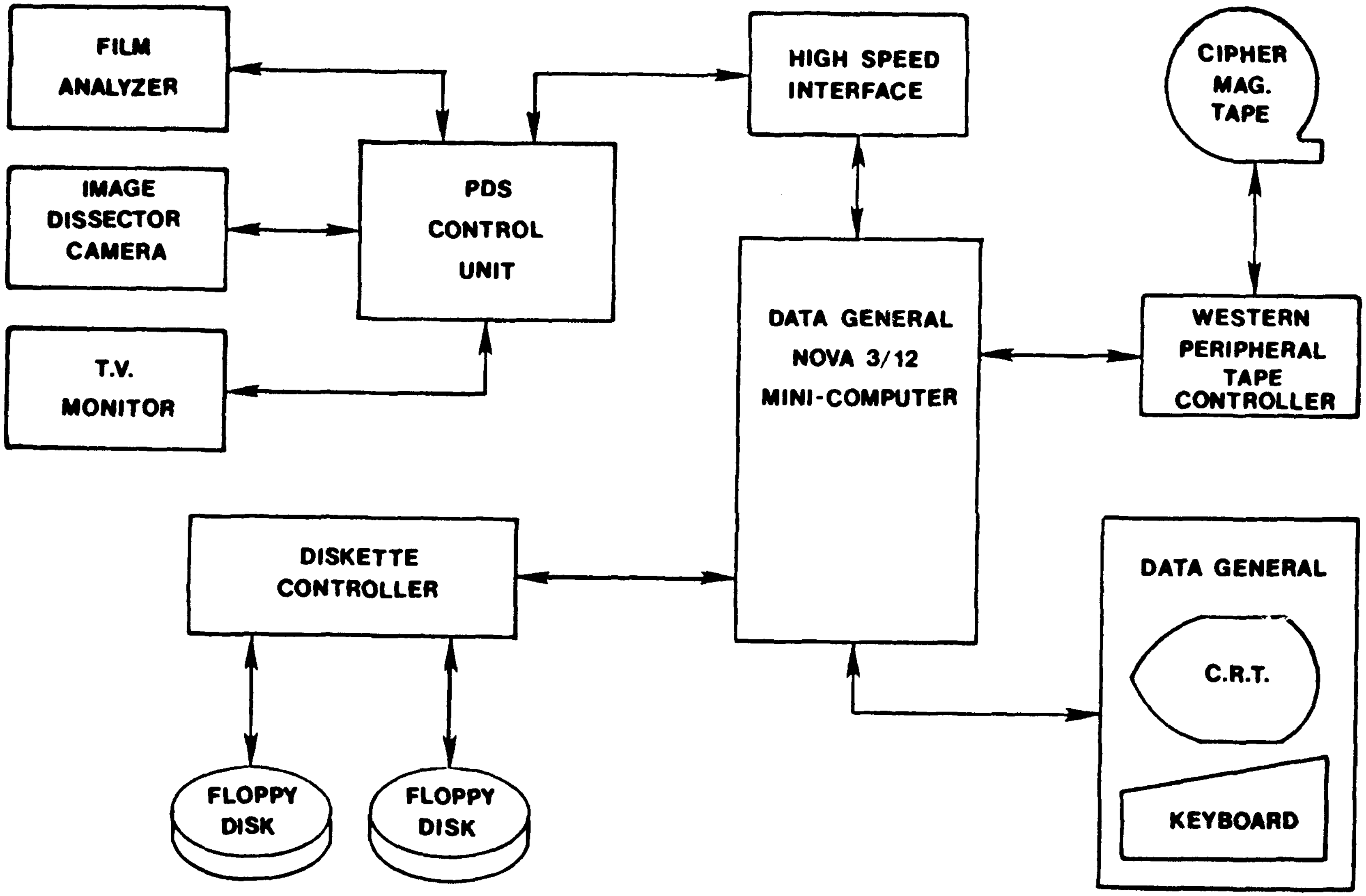


FIGURE A-11: AUTOMATIC FILM READER

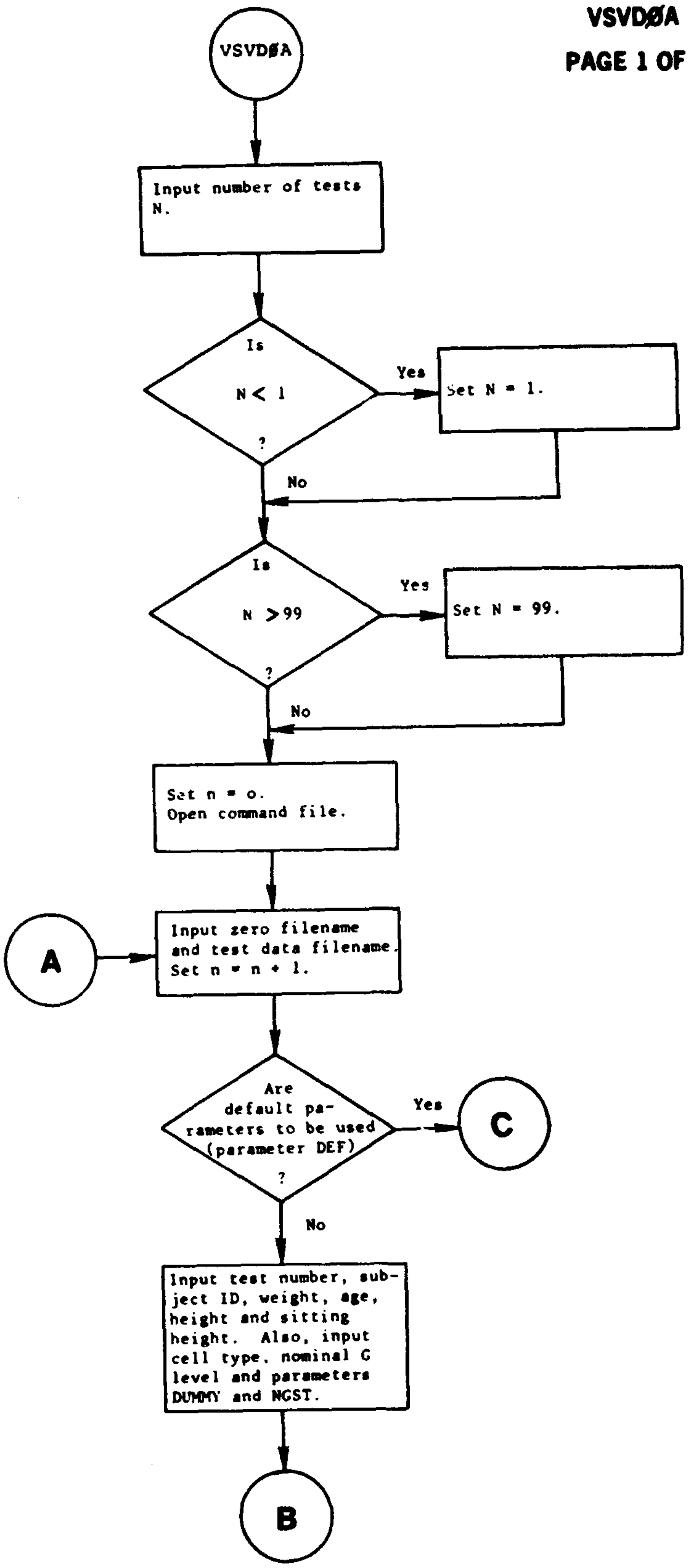


FIGURE A-12a: PROGRAM FLOWCHART FOR VSVDØA

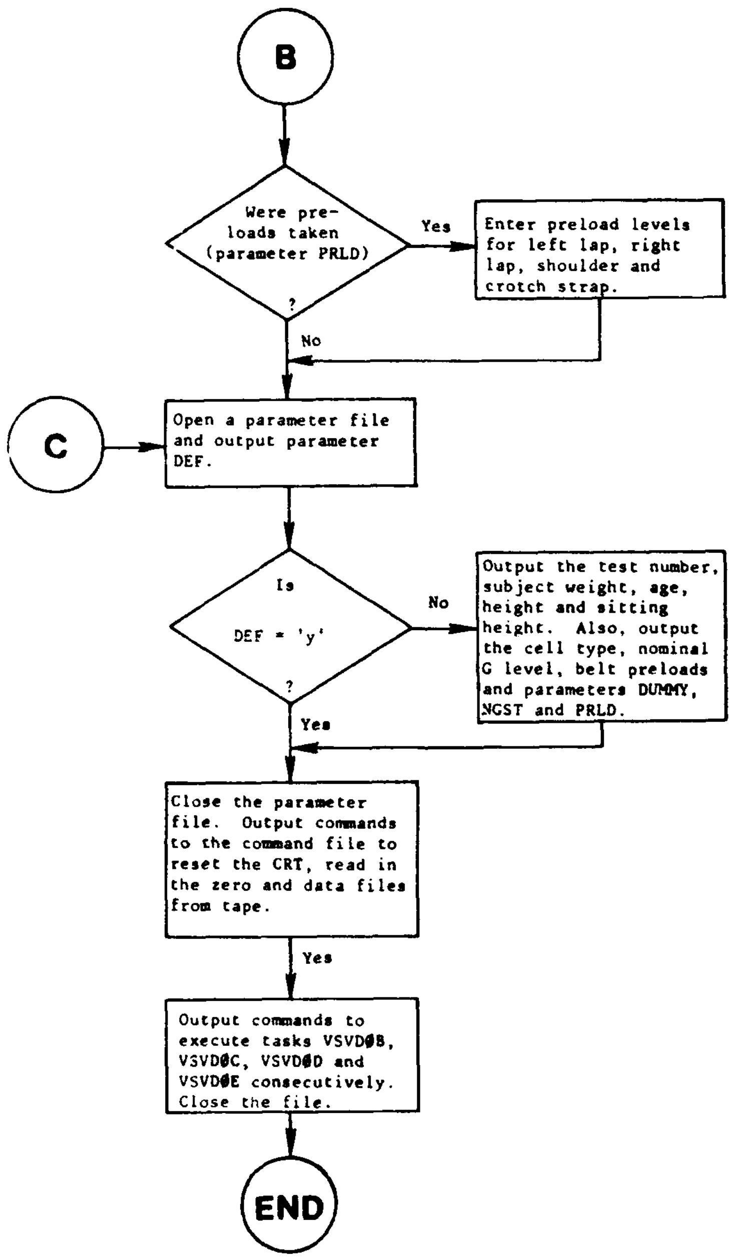


FIGURE A-12b: PROGRAM FLOWCHART FOR VSVDØA

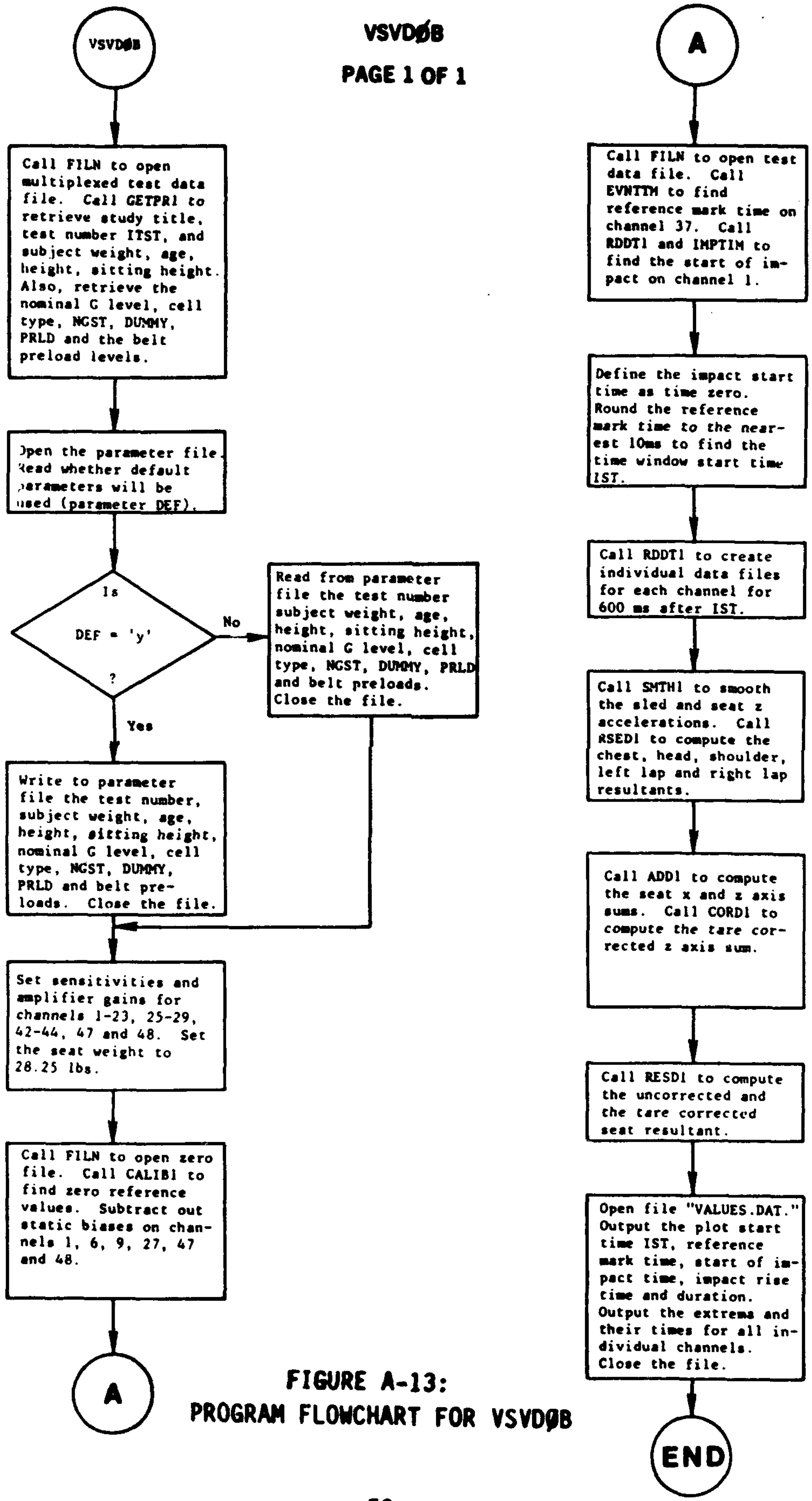
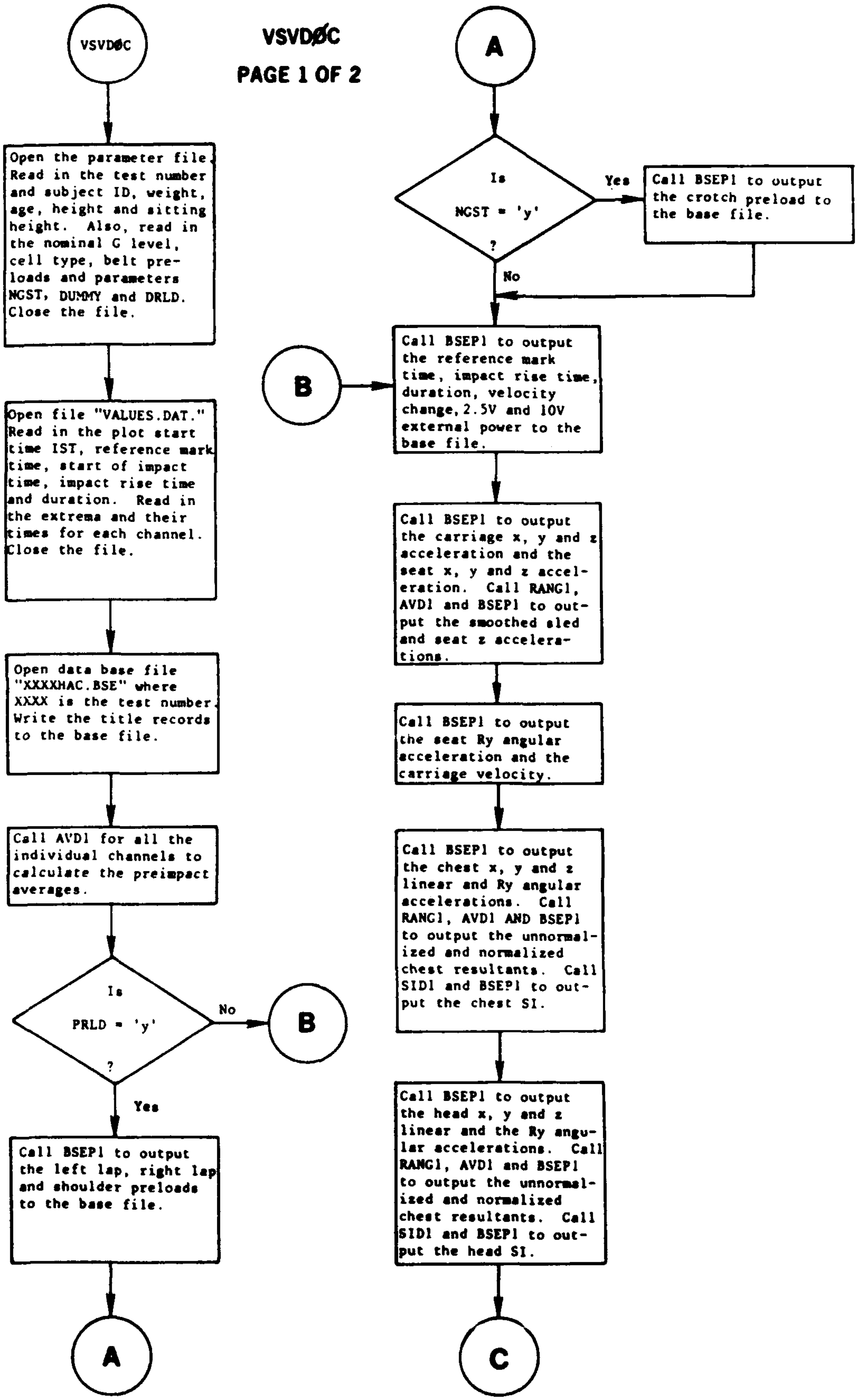


**FIGURE A-13:
PROGRAM FLOWCHART FOR VSVDØB**

FIGURE A-14a:
PROGRAM FLOWCHART FOR VSVDØC



VSVDØC

PAGE 2 OF 2

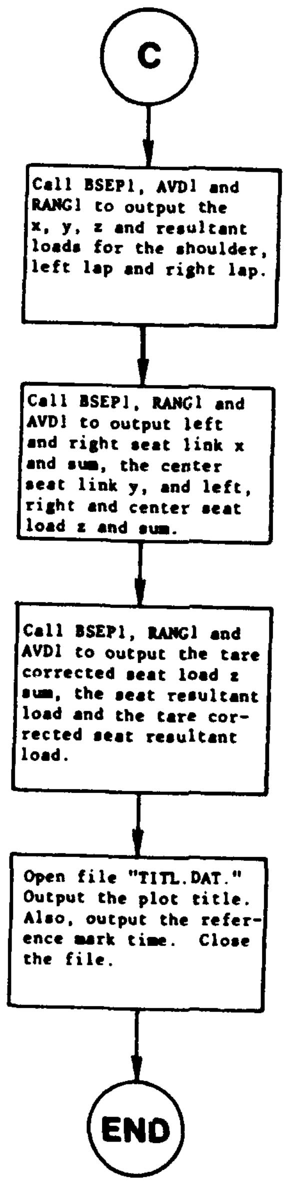


FIGURE A-14b: PROGRAM FLOWCHART FOR VSVDØC

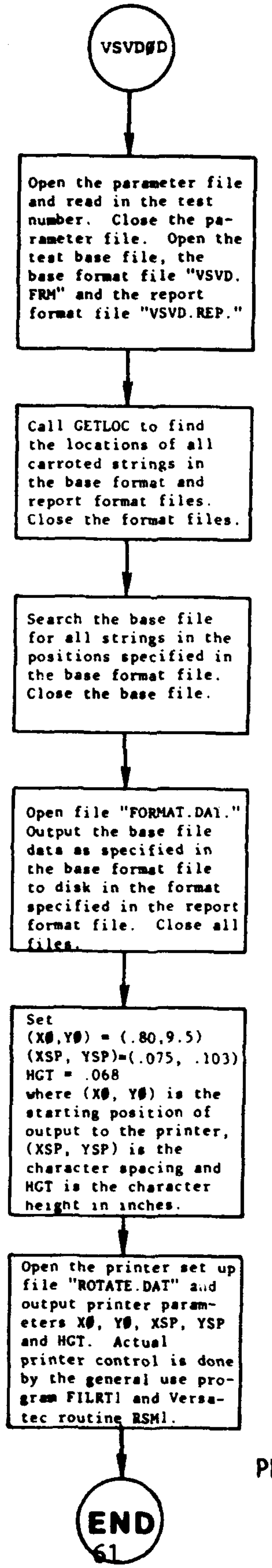


FIGURE A-15:
PROGRAM FLOWCHART FOR VSVDØD

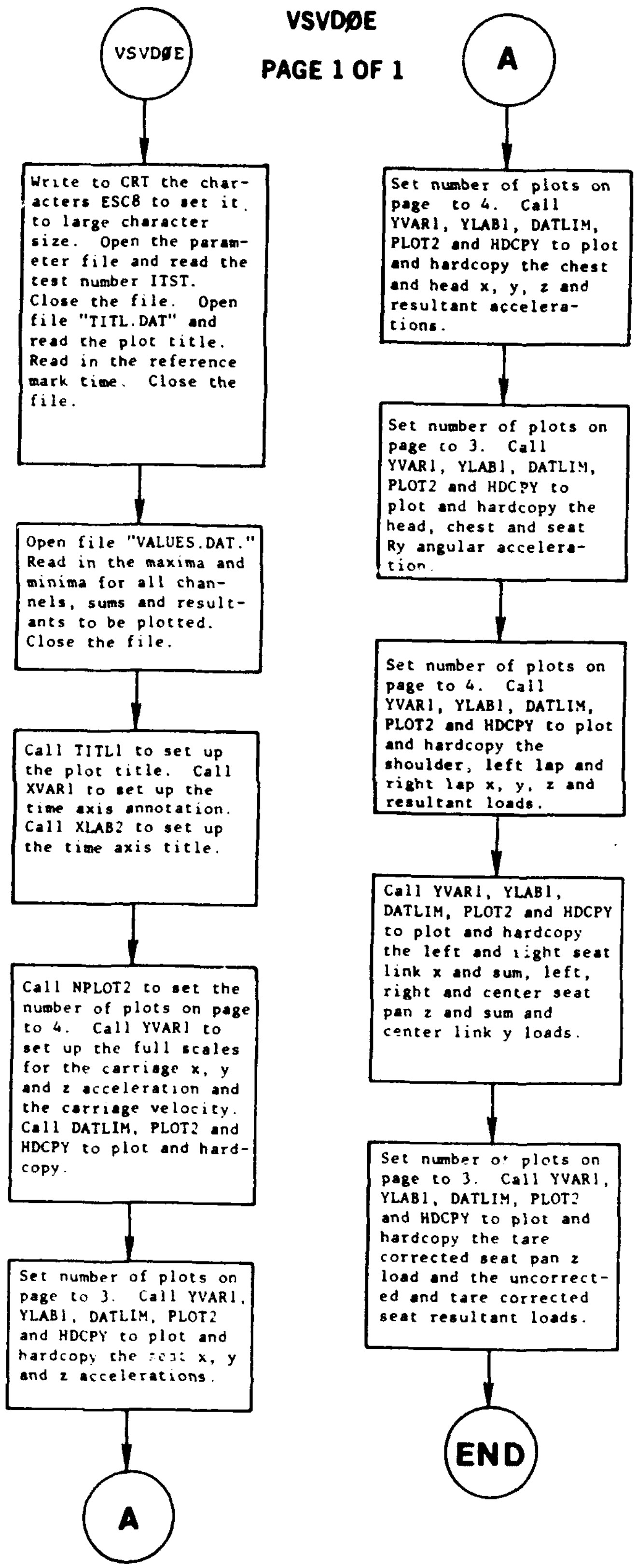


FIGURE A-16: PROGRAM FLOWCHART FOR VSVDØE

ADDENDUM

TEST CONFIGURATION AND DATA ACQUISITION SYSTEM FOR THE EFFECTS OF SEAT CUSHIONS AND SEAT BACK ANGLE ON HUMAN RESPONSE DURING +Gz IMPACT ACCELERATION TEST PROGRAM PHASE II

Prepared under
Contract F33615-86-C-0531

Prepared by
Marshall Z. Miller

DynCorp (formerly Dynalectron Corporation)
AAMRL Division
Building 824, Area B
Wright-Patterson AFB, Ohio 45433

June 1987

TABLE OF CONTENTS

PAGE

INTRODUCTION 65

1. INSTRUMENTATION CHANGES 65
2. SEAT CUSHIONS 66
3. CALIBRATION 66
4. PROCESSING PROGRAMS 66

LIST OF TABLES

TABLE / PAGE

A-3. INSTRUMENTATION REQUIREMENTS
- A-3a. Page 1 of 3 67
- A-3b. Page 2 of 3 68
- A-3c. Page 3 of 3 69

A-4. TYPICAL TRANSDUCER SPECIFICATIONS 70

A-5. TRANSDUCER PRE- AND POST-CALIBRATION
- A-5a. Page 1 of 4 71
- A-5b. Page 2 of 4 72
- A-5c. Page 3 of 4 73
- A-5d. Page 4 of 4 74

LIST OF ILLUSTRATIONS

FIGURE / PAGE

A-17. HUMAN HEAD ACCELERATION PACKAGE 75
A-18. HUMAN THORAXIC ACCELERATION PACKAGE 76
A-19. ACES II SEAT CUSHION 77
A-20. OPERATIONAL F-4 SEAT CUSHION 78
A-21. OPERATIONAL F-4 SEAT CUSHION 79
A-22. CONFOR FOAM F-4 SEAT CUSHION 80
A-23. CONFOR FOAM F-4 SEAT CUSHION 81

INTRODUCTION

This report was prepared by DynCorp (formerly Dynalectron Corporation) for the Harry G. Armstrong Aerospace Medical Research Laboratory (AAMRL/BBP) under Air Force Contract F33615-86-C-0531.

The information provided herein describes all of the instrumentation, calibration, seat cushion and processing program changes of Phase II (when compared to Phase I) of the Effects of Seat Cushions and Seat Back Angle on Human Response During +Gz Impact Acceleration Test Program. Where identical requirements exist for both Phases I and II of the test program, these requirements will not be described herein. One hundred forty-five tests were conducted for Phase II during November and December 1986 and January 1987 on the Vertical Deceleration Tower test facility.

This report is to be used as an addendum to the DynCorp November 1986 test report for Phase I of the Effects of Seat Cushions and Seat Back Angle on Human Response During +Gz Impact Acceleration Test Program.

1. INSTRUMENTATION CHANGES

The instrumentation changes as required by the Phase II Test Plan will be detailed in this section if they were different than required by the Phase I Test Plan. Identical instrumentation as required by both test plans will not be discussed.

Tables A-3a through A-3c list all of the measurement instrumentation used in Phase II of the test program. These tables designate the manufacturer, type, serial number, sensitivity and other pertinent data on each transducer used. Table A-4 lists the manufacturers' typical transducer specifications.

Human head accelerations were measured using three Endevco Model 7264-200 linear accelerometers and one Endevco Model 7302A angular (Ry) accelerometer in Phase II. The Endevco Model 2264-200 linear accelerometers used in Phase I are more prone to temperature drift and offset caused by wiring deflection. The angular accelerometer was not changed. Figure A-17 illustrates the human head acceleration package.

Human thoraxic accelerations measured in Phase II of the test program was not required to be measured in Phase I. Human thoraxic accelerations were measured using two Entran Model EGAXT-100 linear accelerometers for x and z accelerations and one Entran Model EGAXT-250 linear accelerometer for y accelerations. The accelerometers were mounted on a one inch diameter by 1/8 inch thick acrylic plastic pad and were attached to the subjects' intervertebral space between T-4 and T-5 with double-backed tape. Figure A-18 illustrates the human thoraxic acceleration package.

2. SEAT CUSHIONS

The Aces II seat cushion was the only one tested during Phase I of the test program. Figure A-19 illustrates the Aces II seat cushion installed on the VIP seat fixture.

Phase II of the test program included testing the Aces II, Operational F-4 and the Confor Foam F-4 seat cushions.

The Operational F-4 seat cushion uses a double layered contoured foam cushion with a contoured survival kit lid. Figures A-20 and A-21 illustrate the Operational F-4 seat cushion.

The Confor Foam F-4 seat cushion uses a single layer flat foam cushion with a flat survival kit lid. Figures A-22 and A-23 illustrate the Confor Foam F-4 seat cushion.

3. CALIBRATION

Calibrations were performed before and after testing to confirm the accuracy and functional characteristics of the transducers. Pre-program and post-program calibrations for Phase II of the test program are given in Tables A-5a through A-5d.

4. PROCESSING PROGRAMS

The Fortran processing programs that were developed to process the test data for Phase I of the test program are called "VSVDOA," "VSVDOB," "VSVDOC," "VSVDOD," and "VSVDOE." These processing programs were modified for Phase II of the test program to include current transducer sensitivities and the human thorax x, y, z and resultant accelerations.

DIGITAL INSTRUMENTATION REQUIREMENTS

DYNALECTRON CORPORATION

PROGRAM THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz ACCELERATION (PHASE II) DATE 21 NOV 86 THRU 15 JAN 87

FACILITY VERTICAL DECELERATION TOWER RUN 1215 THRU 1359

DATA CHANNEL	DATA POINT	XDUCER MFG & TYPE	S/N	XDUCER SENS	EXCITE V	CHAN	FILTER SERIES	S/N	AMP GAIN	S/N	SAMPLE RATE	FORMAT	F.S. SENS	FILTER HZ	XDUCER ZERO	RANGE	BRIDGE BALANCE RESISTORS	BRIDGE COMPLETION RESISTORS	SPECIAL NOTATIONS
1	CARRIAGE Z	ENDEVCO 2262A-200	FR42	4.196 mv/G	10.00	1	60	1	25	29	1K	1	23.8 G	120	2.5	+5.0 0.0	375K -in Gd.	-	
2	CARRIAGE X	ENDEVCO 2264-200	BX17	2.759 mv/G	10.00	2	60	2	100	5	1K	1	9.06 G	120	2.5	+5.0 0.0	43K +in Gd.	1.58K	
3	CARRIAGE Y	ENDEVCO 7264-200	BH97H	2.783 mv/G	10.00	3	60	3	100	4	1K	1	9.0 G	120	2.5	+5.0 0.0	-	1.5K	
4	HEAD X	ENDEVCO 7264-200	BH58H	2.592 mv/G	10.00	4	60	4	50	23	1K	1	19.3 G	120	2.5	+5.0 0.0	-	1.5K	
5	HEAD Y	ENDEVCO 7264-200	BH60H	2.814 mv/G	10.00	5	60	5	50	27	1K	1	17.8 G	120	2.5	+5.0 0.0	-	1.5K	
6	HEAD Z	ENDEVCO 7264-200	BH63H	2.492 mv/G	10.00	6	60	6	25	10	1K	1	40.1 G	120	2.5	+5.0 0.0	-	1.5K	
7	CHEST X	ENDEVCO 2264-150	BC26	2.795 mv/G	10.00	7	60	7	50	2	1K	1	17.9 G	120	2.5	+5.0 0.0	1.2M -in Gd.	1.65K	
8	CHEST Y	ENDEVCO 2264-150	BB13	2.435 mv/G	10.00	8	60	8	100	37	1K	1	10.3 G	120	2.5	+5.0 0.0	-	1.65K	
9	CHEST Z	ENDEVCO 2264-150	2A20	2.629 mv/G	10.00	9	60	9	25	34	1K	1	38.0 G	120	2.5	+5.0 0.0	156K -in Gd.	1.65K	
10	LEFT SEAT LOAD	STRAINSERT FL2.5u-2SPKT	3294-1	8.02 uv/lb	10.00	10	60	10	201	1	1K	1	1551 lb	120	2.5	+5.0 0.0	-	-	
11	RIGHT SEAT LOAD	STRAINSERT FL2.5u-2SPKT	3294-2	8.03 uv/lb	10.00	11	60	11	201	3	1K	1	1550 lb	120	2.5	+5.0 0.0	-	-	
12	CENTER SEAT LOAD	STRAINSERT FL2.5u-2SPKT	3294-4	8.08 uv/lb	10.00	12	60	12	100	3	1K	1	3094 lb	120	2.5	+5.0 0.0	-	-	
13	LEFT LOAD LINK X	MM/DYN EA06-062 TJ-350	2	10.32 uv/lb	10.00	13	60	13	402	13	1K	1	603 lb	120	2.5	+5.0 0.0	-	-	
14	RIGHT LOAD LINK X	MM/DYN EA06-062 TJ-350	3	10.68 uv/lb	10.00	14	60	14	402	5	1K	1	582 lb	120	2.5	+5.0 0.0	24K -in Gd.	-	

CELL A-H SEAT WEIGHT - 28.25 lb
CELL I SEAT WEIGHT - 29.75 lb
CELL J SEAT WEIGHT - 27.5 lb

PAGE 1 OF 3

TABLE A-3a: INSTRUMENTATION REQUIREMENTS

DIGITAL INSTRUMENTATION REQUIREMENTS

DYNALECTRON CORPORATION

PROGRAM: THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz ACCELERATION (PHASE II) — DATE 21 NOV 86 THRU 15 JAN 87

FACILITY: VERTICAL DECELERATION TOWER — RUN 1215 THRU 1359

DATA CHANNEL	DATA POINT	XDUCER MFG & TYPE	S/N	XDUCER SENS	EXCITE V	CHAN	FILTER SERIES	FILTER S/N	AMP GAIN	AMP S/N	SAMPLE RATE	FORMAT	F.S. SENS	FILTER HZ	XDUCER ZERO	RANGE	BRIDGE BALANCE RESISTORS	BRIDGE COMPLETION RESISTORS	SPECIAL NOTATIONS
15	LEFT LAP LOAD X	GH-3D-SW	15X	5.35 uv/lb	10.00	15	60	15	402	4	1K	1	1162 lb	120	2.5	+5.0 0.0	16K +in Gd.	-	
16	LEFT LAP LOAD Y	GH-3D-SW	15Y	5.32 uv/lb	10.00	16	60	16	800	4	1K	1	587 lb	120	2.5	+5.0 0.0	18K +in Gd.	-	
17	LEFT LAP LOAD Z	GH-3D-SW	15Z	6.30 uv/lb	10.00	17	60	17	402	18	1K	1	987 lb	120	2.5	+5.0 0.0	5K +in Gd.	-	
18	RIGHT LAP LOAD X	GH-3D-SW	21X	5.04 uv/lb	10.00	18	60	18	402	11	1K	1	1234 lb	120	2.5	+5.0 0.0	69K -in Gd.	-	
19	RIGHT LAP LOAD Y	GH-3D-SW	21Y	4.83 uv/lb	10.00	19	60	19	800	1	1K	1	647 lb	120	2.5	+5.0 0.0	17K +in Gd.	-	
20	RIGHT LAP LOAD Z	GH-3D-SW	21Z	6.09 uv/lb	10.00	20	60	20	402	6	1K	1	1021 lb	120	2.5	+5.0 0.0	27K -in Gd.	-	
21	SHOULDER LOAD X	GH-3D-SW	20Z	6.30 uv/lb	10.00	21	60	21	402	10	1K	1	987 lb	120	2.5	+5.0 0.0	46K -in Gd.	-	
22	SHOULDER LOAD Y	GH-3D-SW	20Y	5.81 uv/lb	10.00	22	60	22	800	5	1K	1	538 lb	120	2.5	+5.0 0.0	178K +in Gd.	-	
23	SHOULDER LOAD Z	GH-3D-SW	20X	5.58 uv/lb	10.00	23	60	23	402	8	1K	1	1115lb	120	2.5	+5.0 0.0	29K +in Gd.	-	
25	SEAT X ACCEL.	ENDEVCO 2264-150	BB28	2.700 mv/G	10.00	25	60	25	50	3	1K	1	18.5 G	120	2.5	+5.0 0.0	72.4K +in Gd.	1.65K	
26	SEAT Y ACCEL.	ENDEVCO 2264-200	BV95	2.981 mv/G	10.00	26	60	26	50	15	1K	1	16.8 G	120	2.5	+5.0 0.0	372K +in Gd.	1.47K	
27	SEAT Z ACCEL.	ENDEVCO 2264-200	BW07	2.824 mv/G	10.00	27	60	27	50	1	1K	1	17.7 G	120	2.5	+5.0 0.0	294K -in Gd.	1.47K	
28	CENTER LOAD LINK Y	MM/DYN EA-06-062 TJ-350	5	9.82 uv/lb	10.00	28	60	28	402	7	1K	1	633 lb	120	2.5	+5.0 0.0	-	-	
29	VEL. TACH.	GLOBE 22A672-2	4	.06209 V/F/S	-	29	30	1	1	-	1K	1	80.5 FT/SEC	60	0.0	+5.0 0.0	-	-	

PAGE 2 OF 3

TABLE A-3b: INSTRUMENTATION REQUIREMENTS

DIGITAL INSTRUMENTATION REQUIREMENTS

DYNALECTRON CORPORATION

PROGRAM: THE EFFECTS OF SEAT CUSHION AND SEAT BACK ANGLES DURING +Gz ACCELERATION (PHASE II) DATE 21 NOV 86 THRU 15 JAN 87

FACILITY: VERTICAL DECELERATION TOWER RUN 1215 THRU 1359

DATA CHANNEL	DATA POINT	XDUCER MFG & TYPE	S/N	XDUCER SENS	EXCITE V	CHAN	FILTER SERIES	S/N	AMP GAIN	S/N	SAMPLE RATE	FORMAT	F.S. SENS	FILTER HZ	XDUCER ZERO	RANGE	BRIDGE BALANCE RESISTORS	BRIDGE COMPLETION RESISTORS	SPECIAL NOTATIONS
30	DUMMY HEAD X	ENDEVCO 2264-200	CH74	2.939 mv/G	10.00	30	60	41	50	9	1K	1	17.0 G	120	2.5	+5.0 0.0	190K +in Gd.	1.65K	
31	DUMMY HEAD Y	ENDEVCO 2264-200	BQ42	2.740 mv/G	10.00	31	60	31	50	5	1K	1	18.2 G	120	2.5	+5.0 0.0	220K +in Gd.	1.65K	
32	DUMMY HEAD Z	ENDEVCO 2264-200	CH70	2.676 mv/G	10.00	32	60	32	25	18	1K	1	37.4 G	120	2.5	+5.0 0.0	80K +in Gd.	1.65K	
33	DUMMY HEAD ANG	ENDEVCO 7302	A150	8.26 uv/RAD/SEC^2	10.00	33	60	33	100	11	1K	1	3027 RAD/SEC^2	120	2.5	+5.0 0.0	-	-	
34	THORAX X	ENTRAN EGAXT-100	12Q6S-L1-1	1.005 mv/G	10.00	34	60	34	100	30	1K	1	24.9 G	120	2.5	+5.0 0.0	-	-	
35	THORAX Y	ENTRAN EGAXT-250	12Q6S-L 14-14	.500 mv/G	10.00	35	60	35	201	14	1K	1	24.9 G	120	2.5	+5.0 0.0	-	-	
36	THORAX Z	ENTRAN EGAXT-100	29T6U-A 18 18	1.019 mv/G	10.00	36	60	36	50	26	1K	1	49.1 G	120	2.5	+5.0 0.0	-	-	
37	EVENT	-	-	-	-	37	1000	13	2.5	7	1K	1	5.0 Volt	2000	5.0	+5.0 0.0	-	-	
38	T=0 PULSE	-	-	-	-	38	1000	16	1	-	1K	1	5.0 Volt	2000	0	+5.0 0.0	-	-	
42	HEAD RY ANGULAR	ENDEVCO 7302A	AB12	4.20 uv/RAD/SEC^2	10.00	42	60	42	201	10	1K	1	2961 RAD/SEC^2	120	2.5	+5.0 0.0	-	-	
43	CHEST RY ANGULAR	ENDEVCO 7302A	AB15	6.76 uv/RAD/SEC^2	10.00	43	60	43	201	5	1K	1	1840 RAD/SEC^2	120	2.5	+5.0 0.0	450K -in Gd.	-	
44	SEAT RY ANGULAR	ENDEVCO 7302B	PT47	3.732 uv/RAD/SEC^2	10.00	44	60	44	402	12	1K	1	1666 RAD/SEC^2	120	2.5	+5.0 0.0	-	-	
47	2.5 Volt Bias	-	-	-	-	47	180	14	1	-	1K	1	2.5 Volt	360	2.5	+5.0 0.0	-	-	
48	10 Volt Exc.	-	-	-	-	48	180	19	1	-	1K	1	2.5 Volt	360	2.5	+5.0 0.0	-	-	

PAGE 3 OF 3

TABLE A-3c: INSTRUMENTATION REQUIREMENTS

TYPICAL TRANSDUCER SPECIFICATIONS

MANUFACTURER	MODEL	RANGE	SENSITIVITY (mv)	RESONANCE FREQ (Hz)	FREQUENCY RESPONSE (Hz.)	EXCITATION (Volt)	2 ARM or 4 ARM	ADDITIONAL NOTES
Endevco	:2264-150	±150 G	2.5/G	3400	0-800	10	2 arm	Linear accelerometer
Endevco	:2264-200	±200 G	2.5/G	4700	0-1200	10	2 arm	Linear accelerometer
Endevco	7264-200	±200 G	2.5/G	6000	0-1000	10	2 arm	Linear accelerometer 1000 G overrange
Endevco	2262A-200	±200 G	2.5/G	7000	0-1800	10	4 arm	Linear accelerometer, .7 damping ratio
Endevco	7302	±50,000 Rad/Sec2	.006 /Rad/Sec2	2250	1-600	10	4 arm	Angular Accelerometer, X10 overrange; housing connector
Endevco	7302A	±50,000 Rad/Sec2	.055 /Rad/Sec2	2500	1-600	10	4 arm	Angular accelerometer, X10 overrange
Endevco	7302B	±50,000 Rad/Sec2	.004 /Rad/Sec2	3000	1-600	10	4 arm	Angular accelerometer, X10 overrange
Entran	EGAXT-100	±100 G	2.0/G	1700	0-800	10	4 arm	Linear accelerometer; 10 KG overrange, .7 damping ratio
Entran	EGAXT-250	±250 G	1.0/G	2000	0-1000	10	4 arm	Linear accelerometer; 10 KG overrange, .7 damping ratio
Strainsert	FL2.5U-2SPKT	±2500 Lb	.008/Lb	3600	0-2000	10	4 arm	Load cell; 15 V max exc.; 5 K LB max. overrange

TABLE A-4: TYPICAL TRANSDUCER SPECIFICATIONS

PROGRAM CALIBRATION LOG

PROGRAM: VSBA II **DATES:** 21 NOV 86-15 JAN 87

FACILITY: VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1215-1359

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% CHANGE	NOTES
			DATE	SENS	DATE	SENS		
CARRIAGE Z	ENDEVCO 2262A-200	FR42	18NOV86	4.196	20JAN87	4.171	-.6	
CARRIAGE X	ENDEVCO 2264-200	BX17	18NOV86	2.759	20JAN87	2.779	+.7	
CARRIAGE Y	ENDEVCO 7264-200	BH97H	18NOV86	2.783	20JAN87	2.781	-.1	
HEAD X	ENDEVCO 7264-200	BH58H	18NOV86	2.592	21JAN87	2.595	+.1	
HEAD Y	ENDEVCO 7264-200	BH60H	18NOV86	2.814	21JAN87	2.803	-.4	
HEAD Z	ENDEVCO 7264-200	BH63H	18NOV86	2.492	21JAN87	2.492	0	
CHEST X	ENDEVCO 2264-150	BC26	14OCT86	2.795	21JAN87	2.792	-.1	
CHEST Y	ENDEVCO 2264-150	BE13	15OCT86	2.435	21JAN87	2.443	+.3	
CHEST Z	ENDEVCO 2264-150	2A20	15OCT86	2.629	21JAN87	2.664	+.2	
								All sensitivities in units of mv/G

Page 1 of 4

TABLE A-5a: TRANSDUCER PRE- AND POST-CALIBRATION

PROGRAM CALIBRATION LOG

PROGRAM: VSBA II **DATES:** 21 NOV 86-15 JAN 87

FACILITY: VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1215-1359

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% CHANGE	NOTES
			DATE	SENS	DATE	SENS		
LEFT LOAD LINK X	MM/DYN EA-06-062TJ-350	2	13NOV86	10.32	15JAN87	10.35	+.3	
RIGHT LOAD LINK X	MM/DYN EA-06-062TJ-350	3	13NOV86	10.68	15JAN87	10.66	-.2	
CENTER LOAD LINK Y	MM/DYN EA-06-062TJ-350	5	13NOV86	9.82	15JAN87	9.86	+.4	
LEFT LAP LOAD X	GM-3D-SW	15X	13NOV86	5.35	16JAN87	5.36	+.2	
LEFT LAP LOAD Y	GM-3D-SW	15Y	13NOV86	5.32	16JAN87	5.32	0	
LEFT LAP LOAD Z	GM-3D-SW	15Z	13NOV86	6.30	16JAN87	6.33	+.5	
RIGHT LAP LOAD X	GM-3D-SW	21X	13NOV86	5.04	16JAN87	5.04	0	
RIGHT LAP LOAD Y	GM-3D-SW	21Y	13NOV86	4.83	16JAN87	4.80	-.6	
RIGHT LAP LOAD Z	GM-3D-SW	21Z	13NOV86	6.09	16JAN87	6.05	-.2	
SHOULDER LOAD X	GM-3D-SW	20Z	14NOV86	6.30	16JAN87	6.29	-.2	All sensitivities in units of uv/lb.

Page 2 of 4

TABLE A-5b: TRANSDUCER PRE- AND POST-CALIBRATION

PROGRAM CALIBRATION LOG

PROGRAM: VSBA II **DATES:** 21 NOV 86-15 JAN 87

FACILITY: VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1215-1359

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% CHANGE	NOTES
			DATE	SENS	DATE	SENS		
SHOULDER LOAD Y	GM-3D-SW	20Y	14NOV86	5.81	16JAN87	5.73	-1.2	
SHOULDER LOAD Z	GM-3D-SW	20X	14NOV86	5.58	16JAN87	5.57	-.2	
HEAD RY ANGULAR	ENDEVCO 7302A	AB12	19NOV86	4.20 $\mu v/RAD/SEC^2$	22JAN87	4.22 $\mu v/RAD/SEC^2$	+.4	
CHEST RY ANGULAR	ENDEVCO 7302A	AB15	19NOV86	6.76 $\mu v/RAD/SEC^2$	22JAN87	6.81 $\mu v/RAD/SEC^2$	+.8	
SEAT RY ANGULAR	ENDEVCO 7302B	PT47	22AUG86	3.732 $\mu v/RAD/SEC^2$	22JAN87	3.719 $\mu v/RAD/SEC^2$	-.3	
								Unless noted otherwise, all
								sens. in units of uv/lb.

Page 3 of 4

TABLE A-5c: TRANSDUCER PRE- AND POST-CALIBRATION

PROGRAM CALIBRATION LOG

PROGRAM: VSBA II **DATES:** 21 NOV 86-15 JAN 87

FACILITY: VERTICAL DECELERATION TOWER **RUN NUMBERS:** 1215-1359

DATA POINT	TRANSDUCER MFG. & MODEL	SERIAL NUMBER	PRE-CAL		POST-CAL		% CHANGE	NOTES
			DATE	SENS	DATE	SENS		
SEAT X ACCELERATION	ENDEVCO 2264-150	BB28	18NOV86	2.700	20JAN87	2.714	+.5	
SEAT Y ACCELERATION	ENDEVCO 2264-200	BV95	18NOV86	2.981	20JAN87	2.979	-.1	
SEAT Z ACCELERATION	ENDEVCO 2264-200	BW07	18NOV86	2.824	20JAN87	2.835	+.4	
DUMMY HEAD X	ENDEVCO 2264-200	CH74	22AUG86	2.939	21JAN87	2.943	+.1	
DUMMY HEAD Y	ENDEVCO 2264-200	BQ42	22AUG86	2.740	21JAN87	2.736	-.1	
DUMMY HEAD Z	ENDEVCO 2264-200	CH70	22AUG86	2.676	21JAN87	2.690	+.5	
DUMMY HEAD ANGULAR	ENDEVCO 7302	A150	19NOV86	8.257 uv/RAD/SEC^2	22JAN87	8.154 uv/RAD/SEC^2	-1.2	
								Unless noted otherwise, all
								sens. in units of mv/G.

Page 4 of 4

TABLE A-5d: TRANSDUCER PRE- AND POST-CALIBRATION

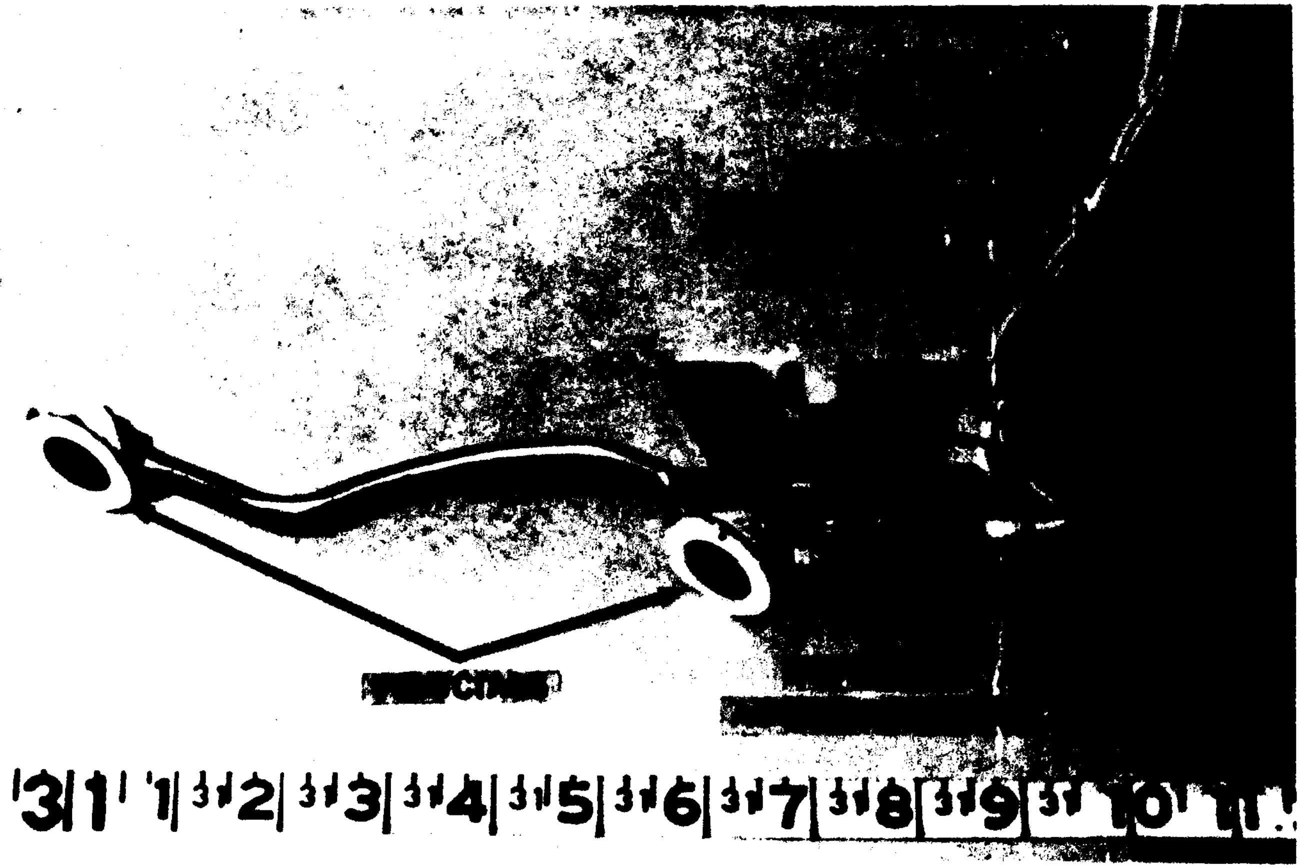


FIGURE A-17: HUMAN HEAD ACCELERATION PACKAGE

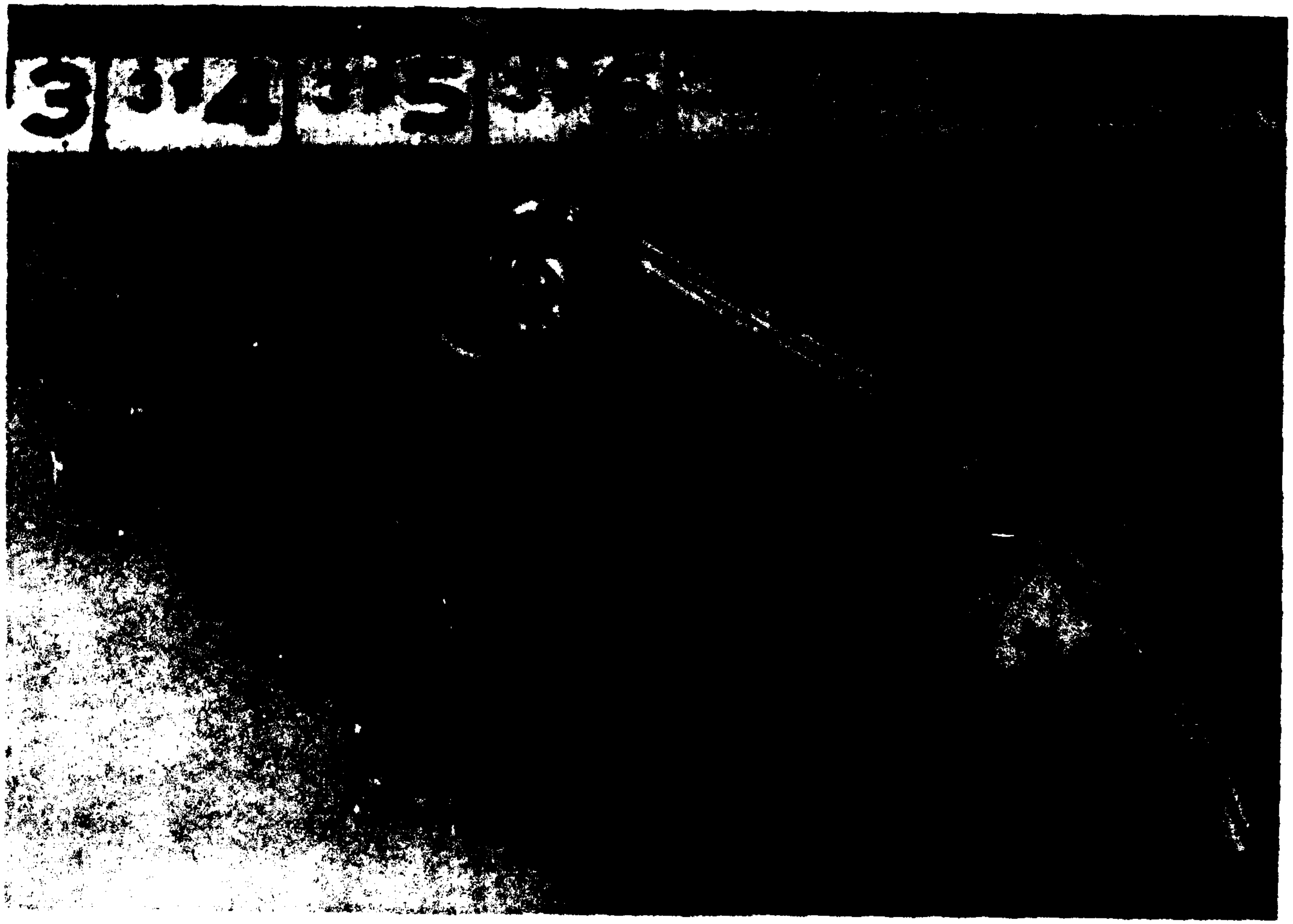


FIGURE A-18: HUMAN THORAXIC ACCELERATION PACKAGE

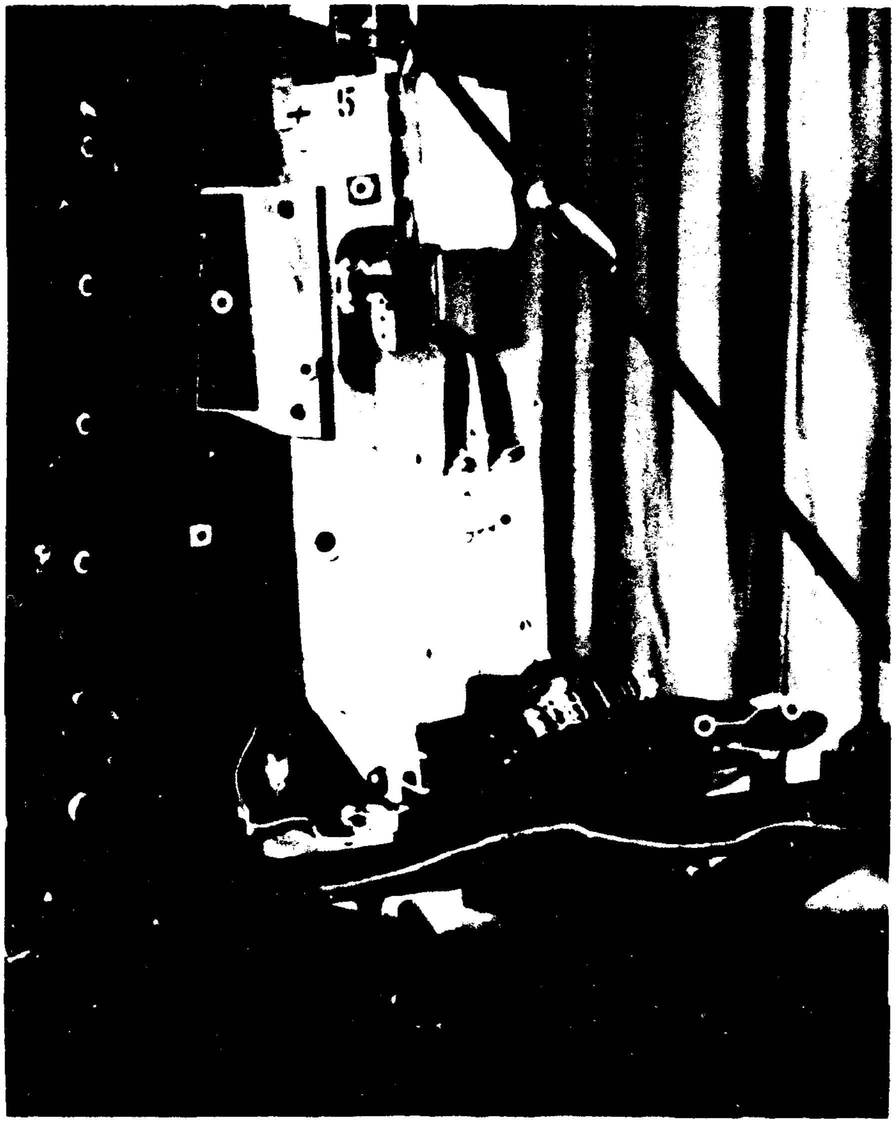


FIGURE A-19: ACES II SEAT CUSHION

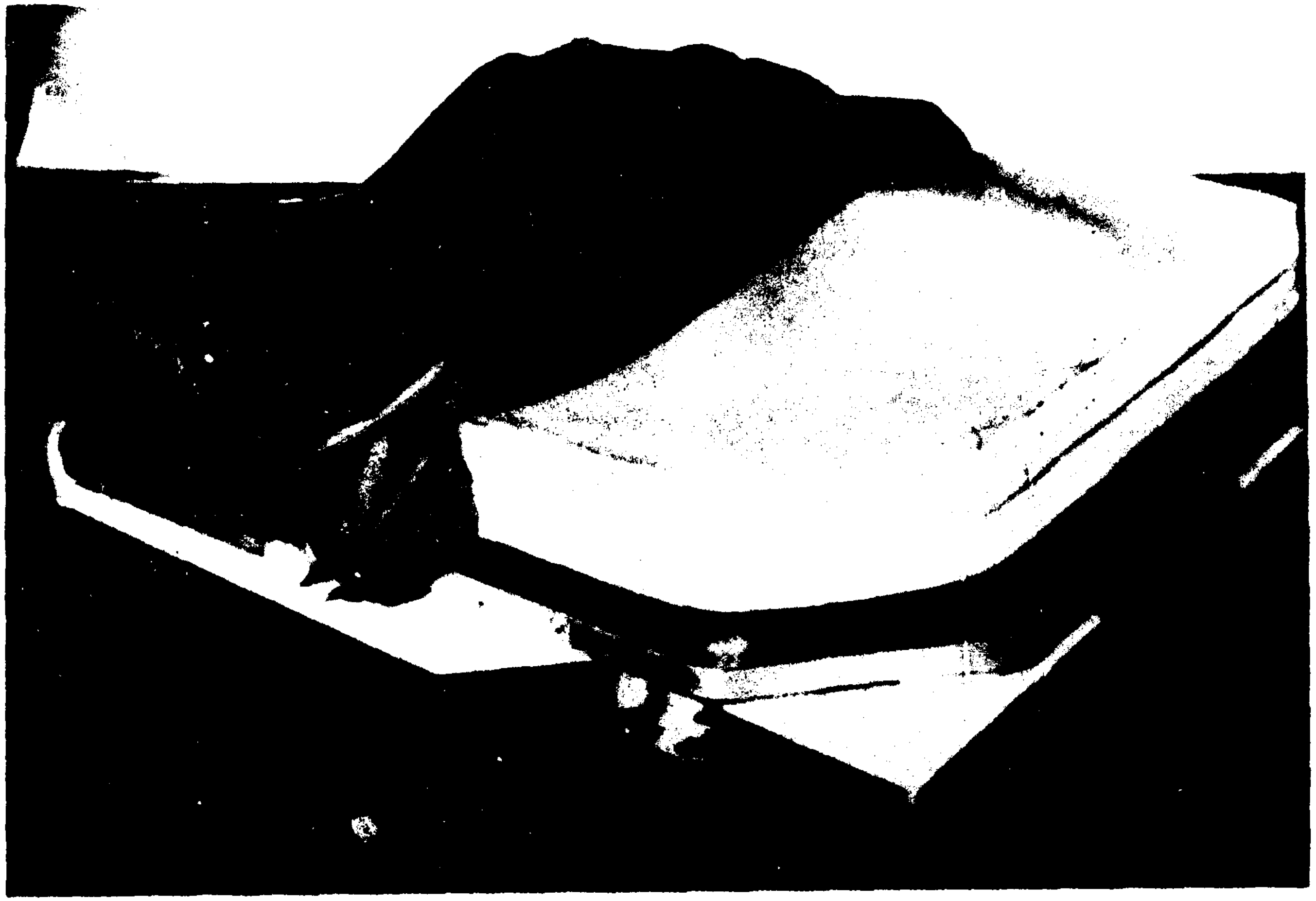


FIGURE A-20: OPERATIONAL F-4 SEAT CUSHION

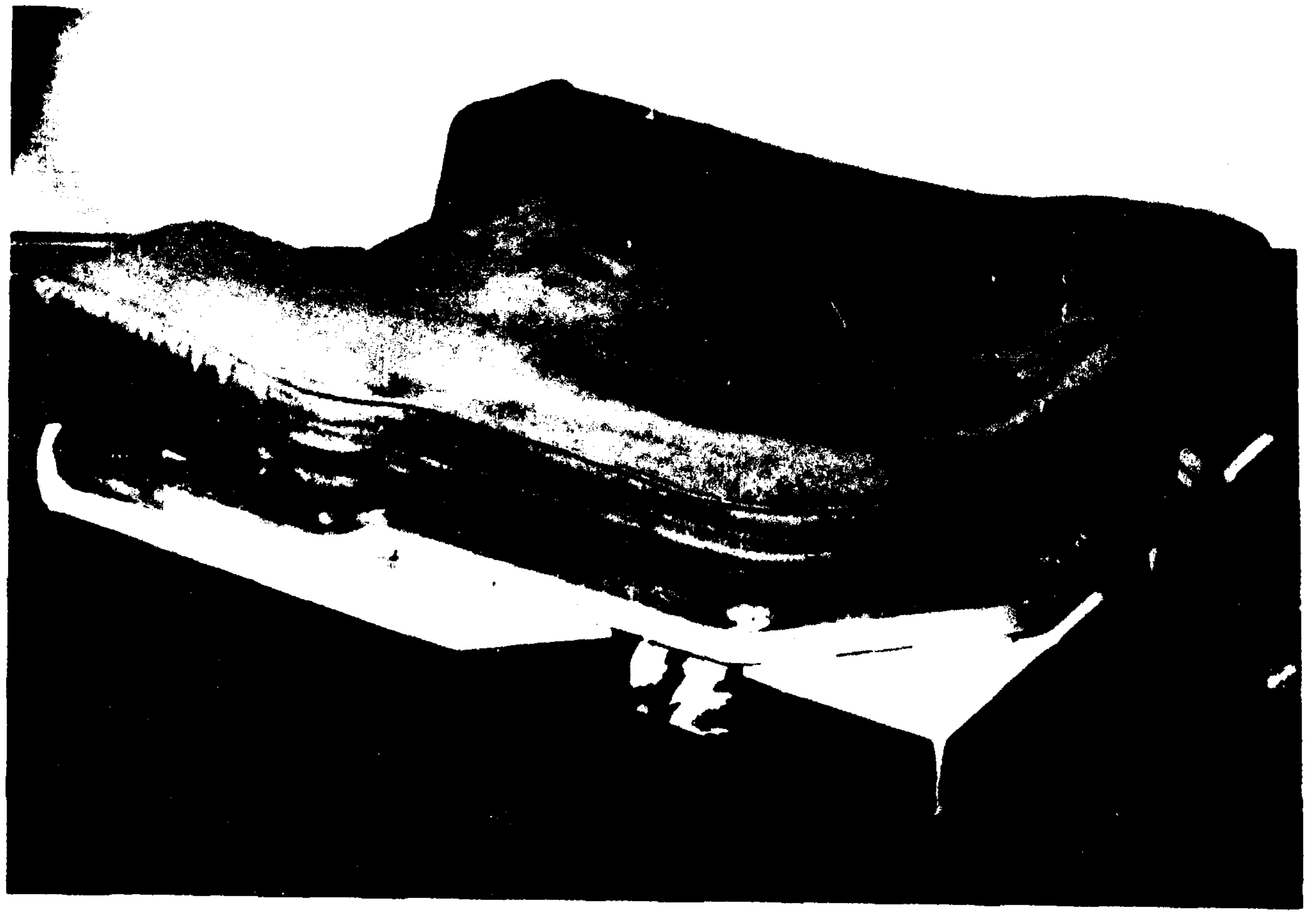


FIGURE A-21: OPERATIONAL F-4 SEAT CUSHION

FIGURE A-22: CONFOR FOAM F-4 SEAT CUSHION

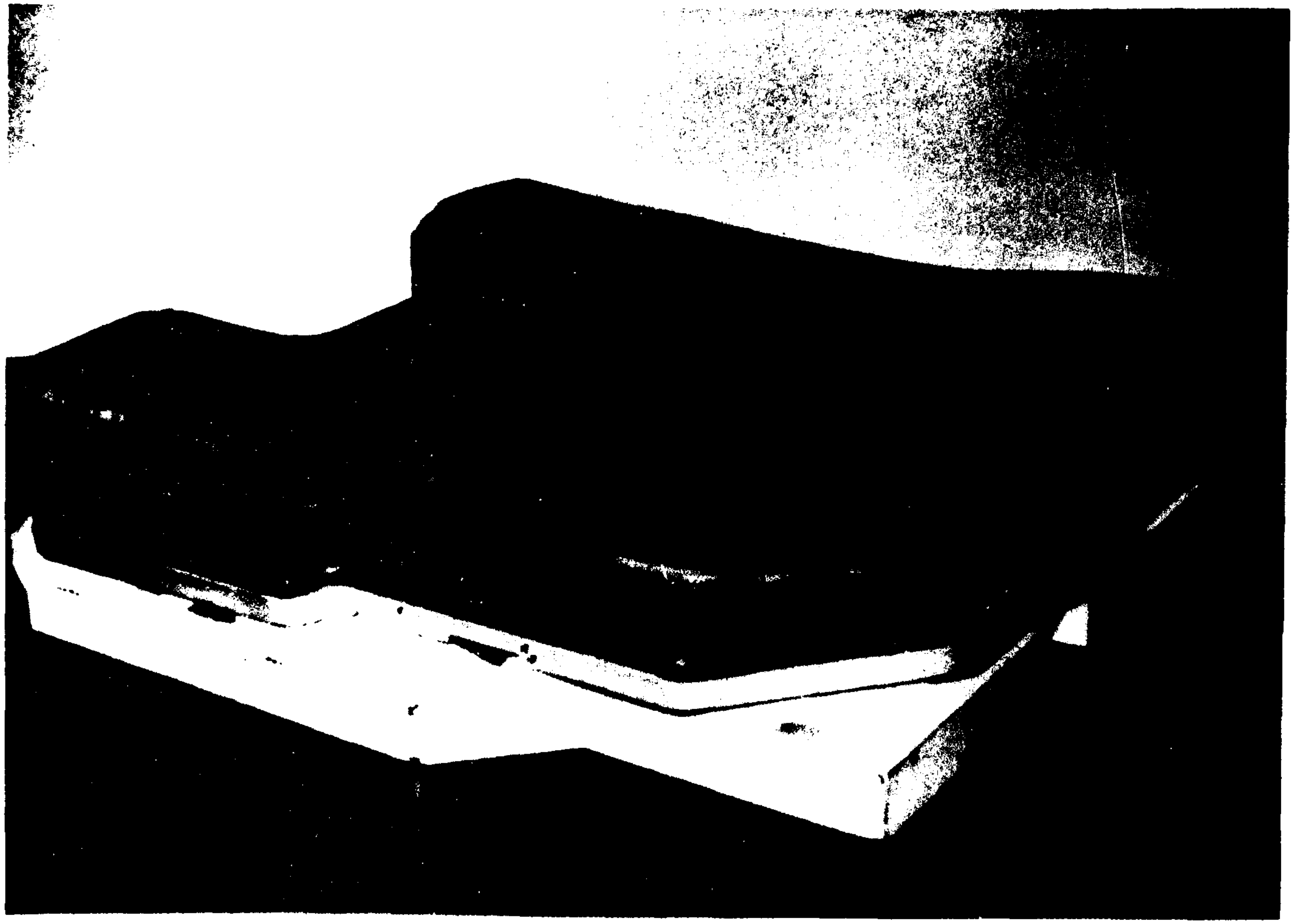


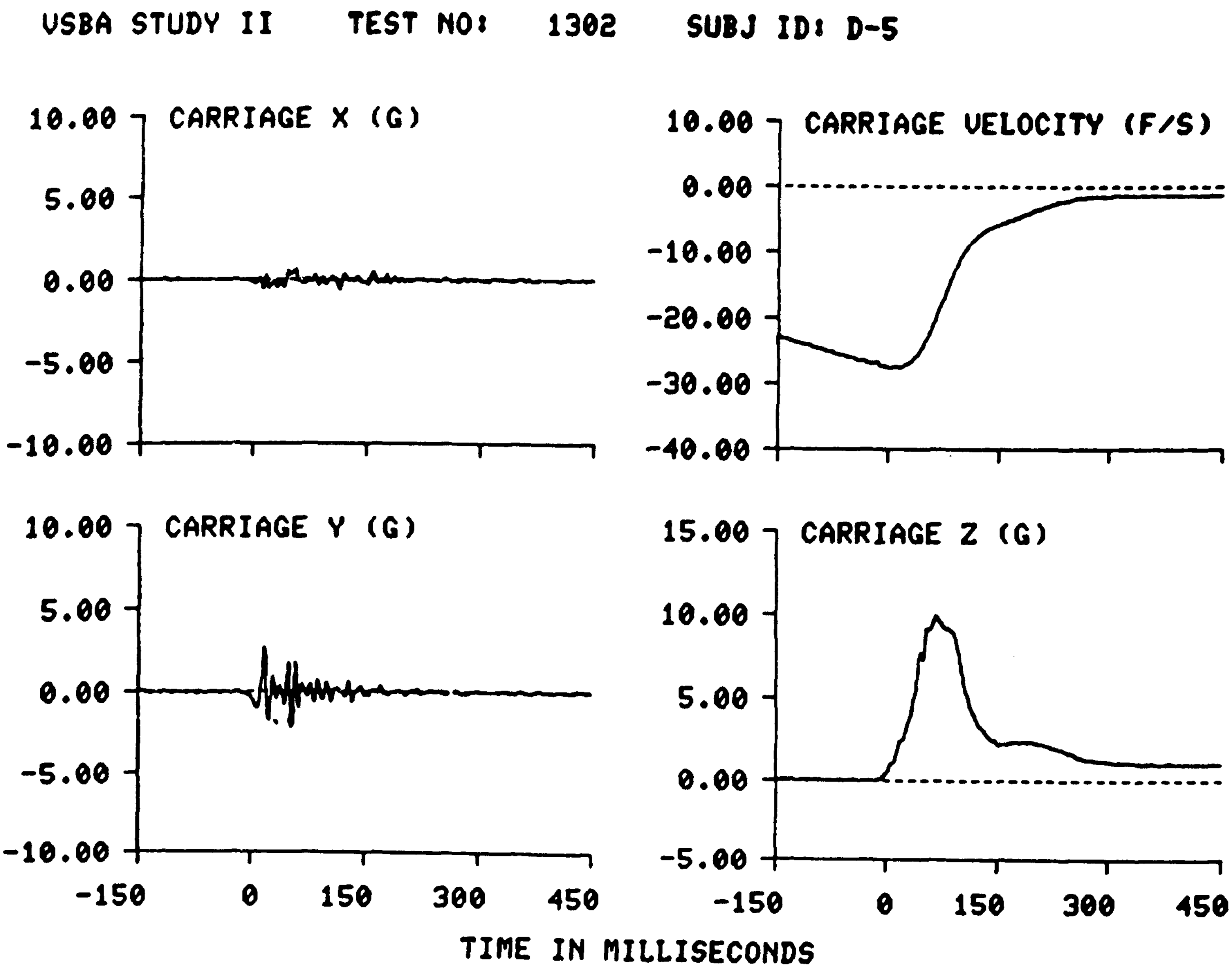
FIGURE A-23: CONFOR FOAM F-4 SEAT CUSHION

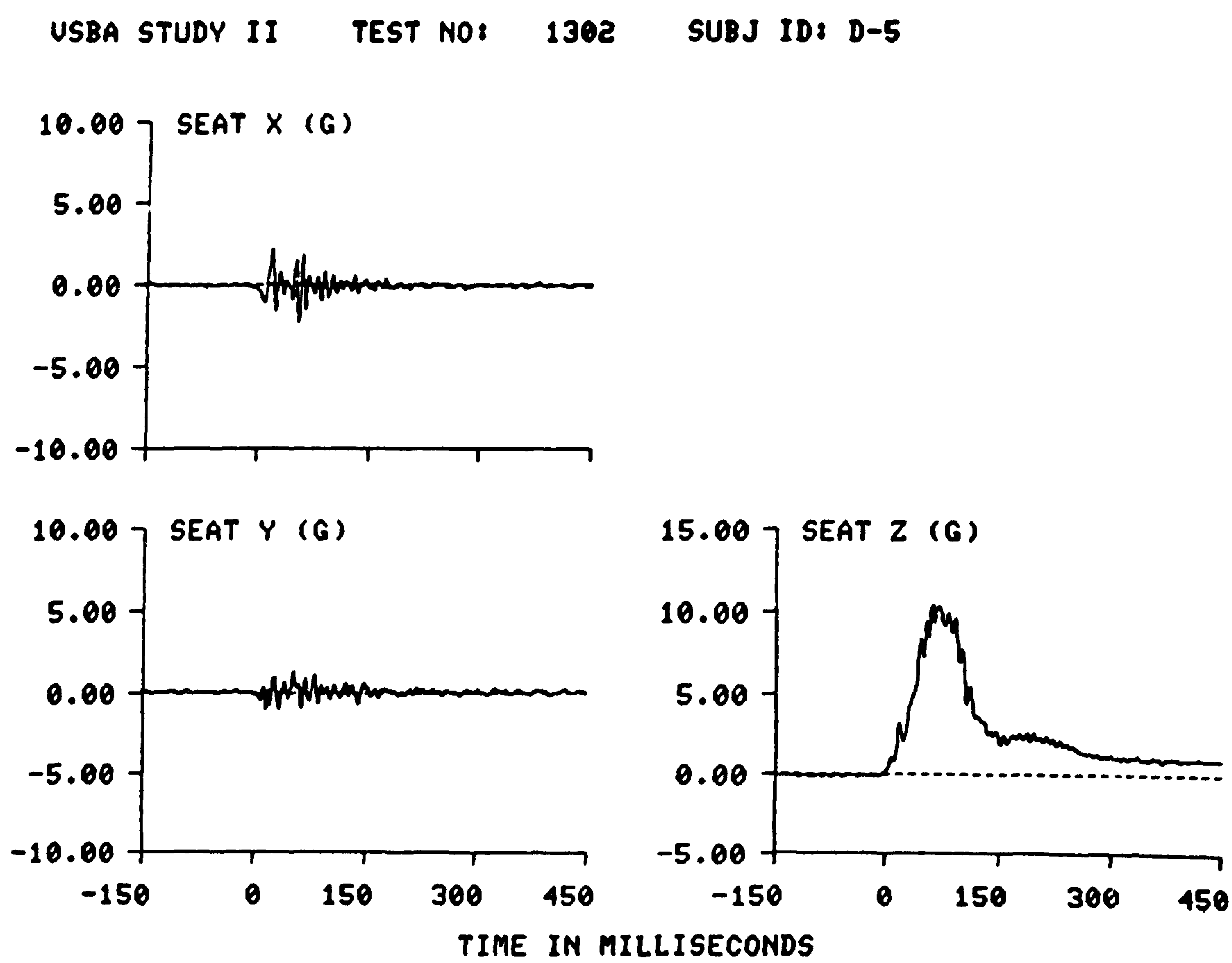
APPENDIX B

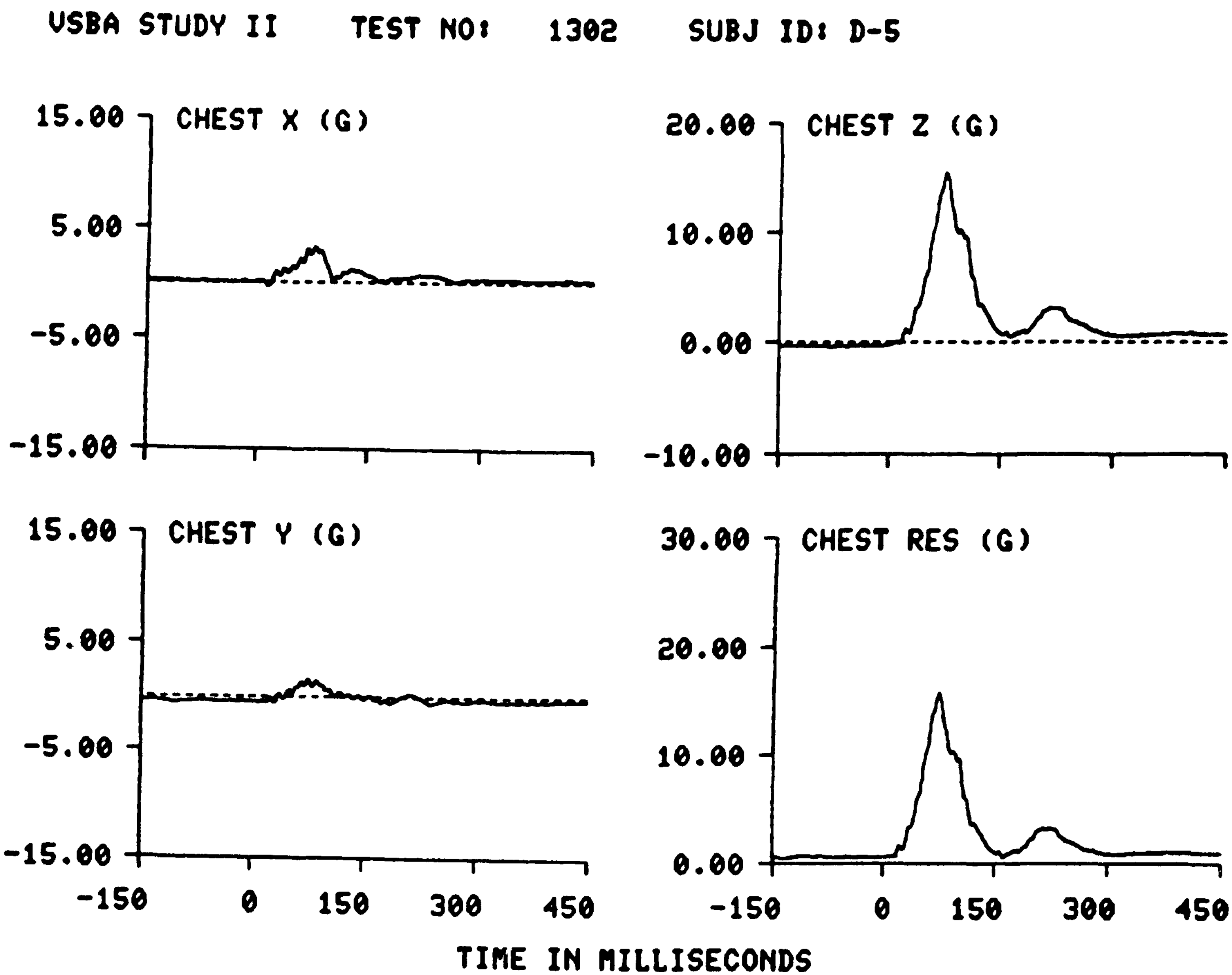
REPRESENTATIVE TEST DATA

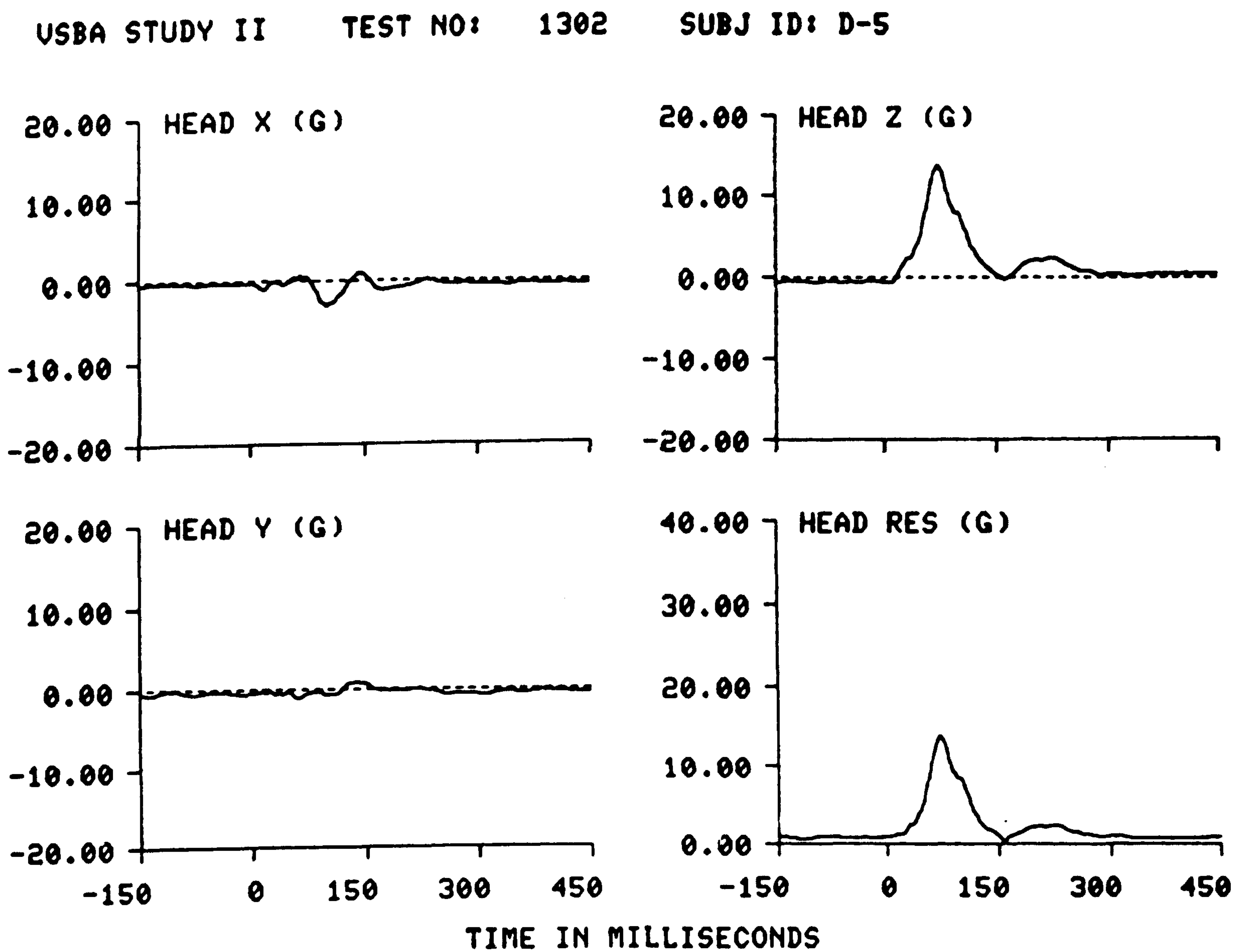
VSBA STUDY II TEST: 1302 SUBJ: D-5 WT: 174.0 NOM G: 10.0 CELL: E

DATA ID	IMMEDIATE PREIMPACT	MAXIMUM VALUE	MINIMUM VALUE	TIME OF MAXIMUM	TIME OF MINIMUM
REFERENCE MARK				-153.	
2.5V EXT PWR		2.51	2.50	171.	60.
10V EXT PWR		10.01	9.99	34.	162.
CARRIAGE ACCELERATION (G)					
X AXIS	0.01	0.81	-0.58	55.	113.
Y AXIS	-0.07	2.71	-2.19	17.	54.
Z AXIS	0.04	9.90	0.46	67.	0.
Z AXIS (SM)	0.05	9.66	0.52	69.	0.
SEAT ACCELERATION (G)					
X AXIS	-0.06	2.22	-2.33	16.	53.
Y AXIS	0.05	1.29	-1.01	52.	33.
Z AXIS	-0.10	10.38	0.24	61.	0.
Z AXIS (SM)	-0.10	10.06	0.28	70.	0.
RT	-5.86	22.85	-30.85	102.	107.
CARRIAGE VELOCITY (F/S)	-26.89	-1.21	-27.59	366.	15.
CHEST ACCELERATION (G)					
X AXIS	0.06	3.29	-0.38	76.	14.
Y AXIS	-0.44	1.58	-0.68	76.	241.
Z AXIS	-0.30	15.43	-0.23	76.	0.
RESULTANT	0.54	15.86	0.52	76.	17.
NORM RESULTANT	0.06	1.64	0.05	76.	17.
SI		30.94			
RT	-2.51	189.55	-286.80	71.	91.
HEAD ACCELERATION (G)					
X AXIS	-0.28	0.93	-3.00	141.	98.
Y AXIS	-0.55	0.86	-1.09	136.	59.
Z AXIS	-0.45	13.74	-0.62	72.	9.
RESULTANT	0.77	13.76	0.14	72.	157.
NORM RESULTANT	0.08	1.42	0.01	72.	157.
SI		22.66			
RT	4.29	126.34	-119.36	72.	90.
THORAX ACCELERATION (G)					
X AXIS	-0.1	0.37	-4.43	19.	86.
Y AXIS	1.40	2.21	-0.82	136.	76.
Z AXIS	-0.19	13.70	-0.13	82.	0.
RESULTANT	1.43	14.12	1.18	83.	311.
NORM RESULTANT	0.15	1.46	0.12	83.	311.
SHOULDER LOADS (LB)					
X AXIS	79.49	113.49	33.57	83.	447.
Y AXIS	7.52	19.25	2.04	83.	321.
Z AXIS	3.83	41.06	3.19	89.	0.
RESULTANT	79.94	122.22	34.57	94.	447.
LAP LOADS (LB)					
LEFT X AXIS	60.84	93.33	13.15	88.	404.
LEFT Y AXIS	27.85	39.94	6.47	87.	408.
LEFT Z AXIS	60.93	64.24	11.94	0.	407.
LEFT RESULTANT	90.53	119.41	19.54	88.	416.
RIGHT X AXIS	49.29	78.37	14.23	91.	192.
RIGHT Y AXIS	15.65	17.24	1.72	89.	217.
RIGHT Z AXIS	61.31	63.82	8.70	0.	49.
RIGHT RESULTANT	80.21	98.02	20.05	91.	199.
SEAT LOADS (LB)					
LEFT LINK X AXIS	-0.29	15.07	-1.19	128.	25.
RIGHT LINK X AXIS	-9.13	-3.62	-104.32	18.	85.
X AXIS	-9.42	2.42	-103.76	18.	83.
CENTER LINK Y AXIS	-8.72	-9.52	-35.48	0.	61.
LEFT PAN Z AXIS	40.47	499.52	20.49	83.	340.
RIGHT PAN Z AXIS	39.36	715.19	43.23	85.	341.
CENTER PAN Z AXIS	72.32	1481.34	86.48	73.	0.
Z AXIS SUM	152.15	2635.62	176.55	75.	0.
Z AXIS MINUS TARE	183.26	2399.48	197.93	76.	0.
RESULTANT	152.69	2637.52	177.12	75.	0.
RESULTANT MINUS TARE	183.71	2401.62	198.44	76.	0.

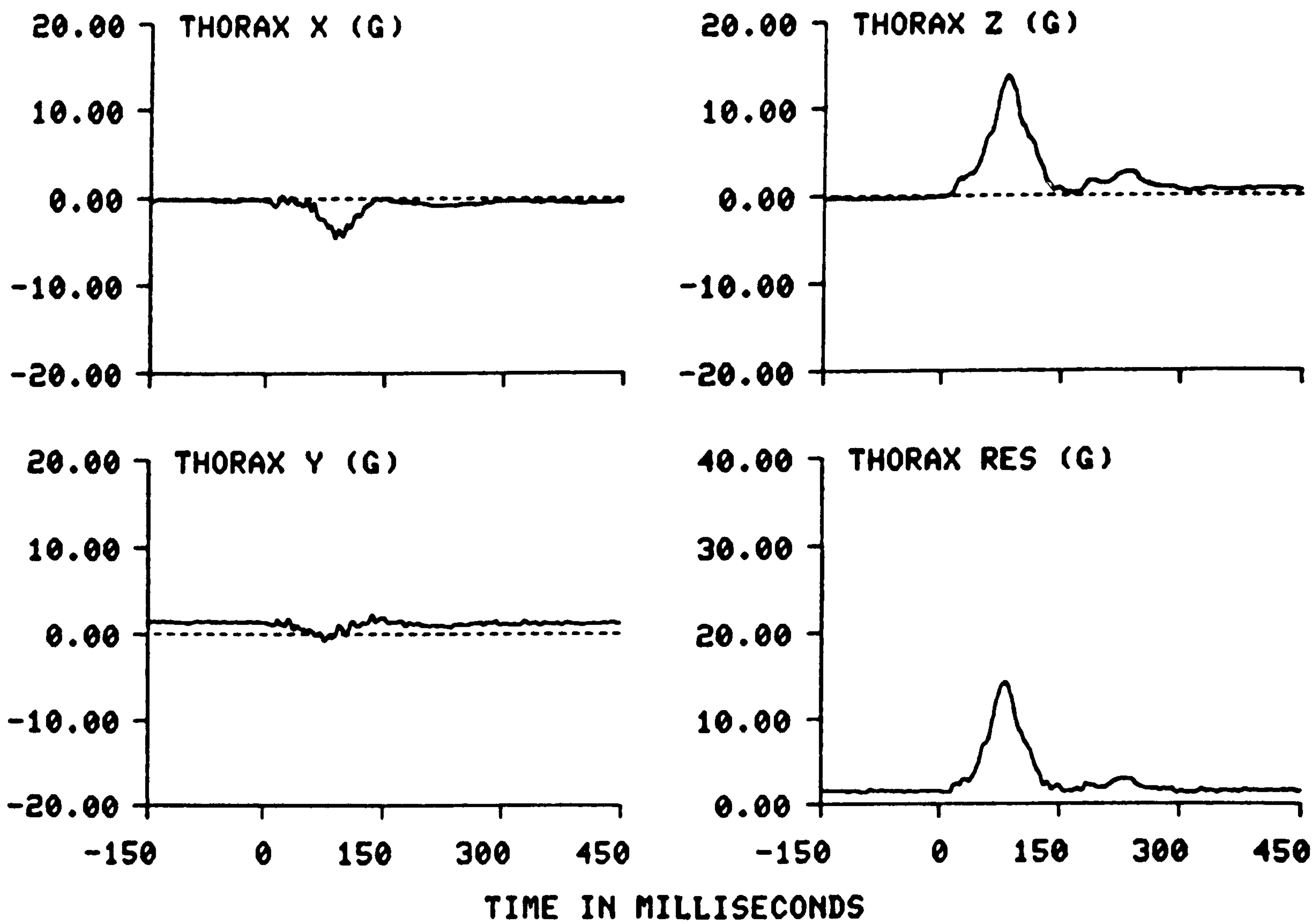

USBA STUDY II TEST NO: 1302 SUBJ ID: D-5
CARRIAGE X (G)
CARRIAGE VELOCITY (F/S)
CARRIAGE Y (G)
CARRIAGE Z (G)
10.00
5.00
0.00
-5.00
-10.00
-10.00
-20.00
-30.00
-40.00
15.00
-150
0
150
300
450
TIME IN MILLISECONDS


USBA STUDY II TEST NO: 1302 SUBJ ID: D-5
SEAT X (G)
10.00
5.00
0.00
-5.00
-10.00
SEAT Y (G)
10.00
5.00
0.00
-5.00
-10.00
-150
0
150
300
450
SEAT Z (G)
15.00
10.00
5.00
0.00
-5.00
-150
0
150
300
450
TIME IN MILLISECONDS

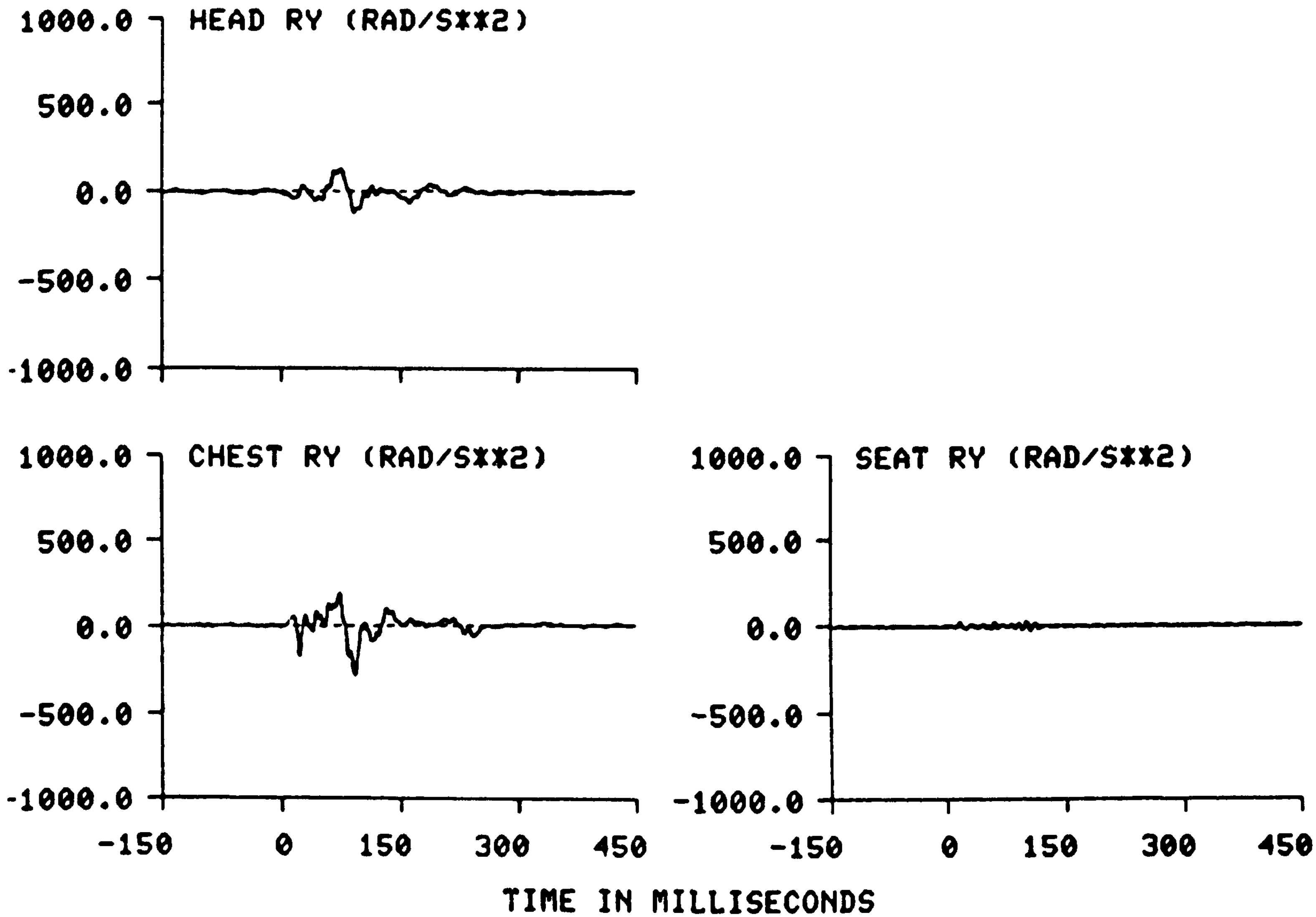

USBA STUDY II TEST NO: 1302 SUBJ ID: D-5
CHEST X (G)
15.00
5.00
-5.00
-15.00
CHEST Z (G)
20.00
10.00
0.00
-10.00
CHEST Y (G)
15.00
5.00
-5.00
-15.00
CHEST RES (G)
30.00
20.00
10.00
0.00
-150
0
150
300
450
-150
0
150
300
450
TIME IN MILLISECONDS

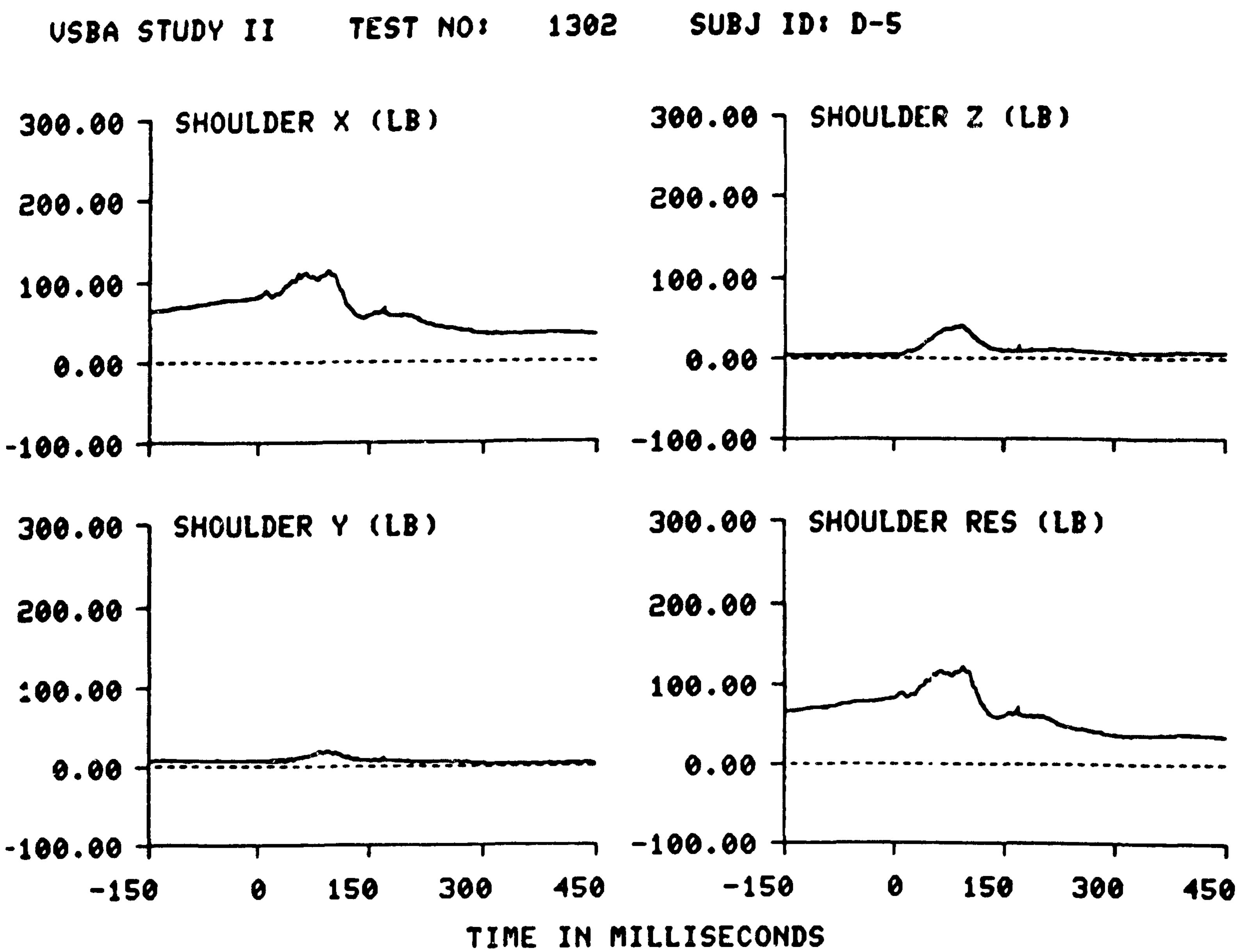

USBA STUDY II TEST NO: 1302 SUBJ ID: D-5
HEAD X (G)
HEAD Z (G)
HEAD Y (G)
HEAD RES (G)
20.00
10.00
0.00
-10.00
-20.00
40.00
30.00
-150
0
150
300
450
TIME IN MILLISECONDS

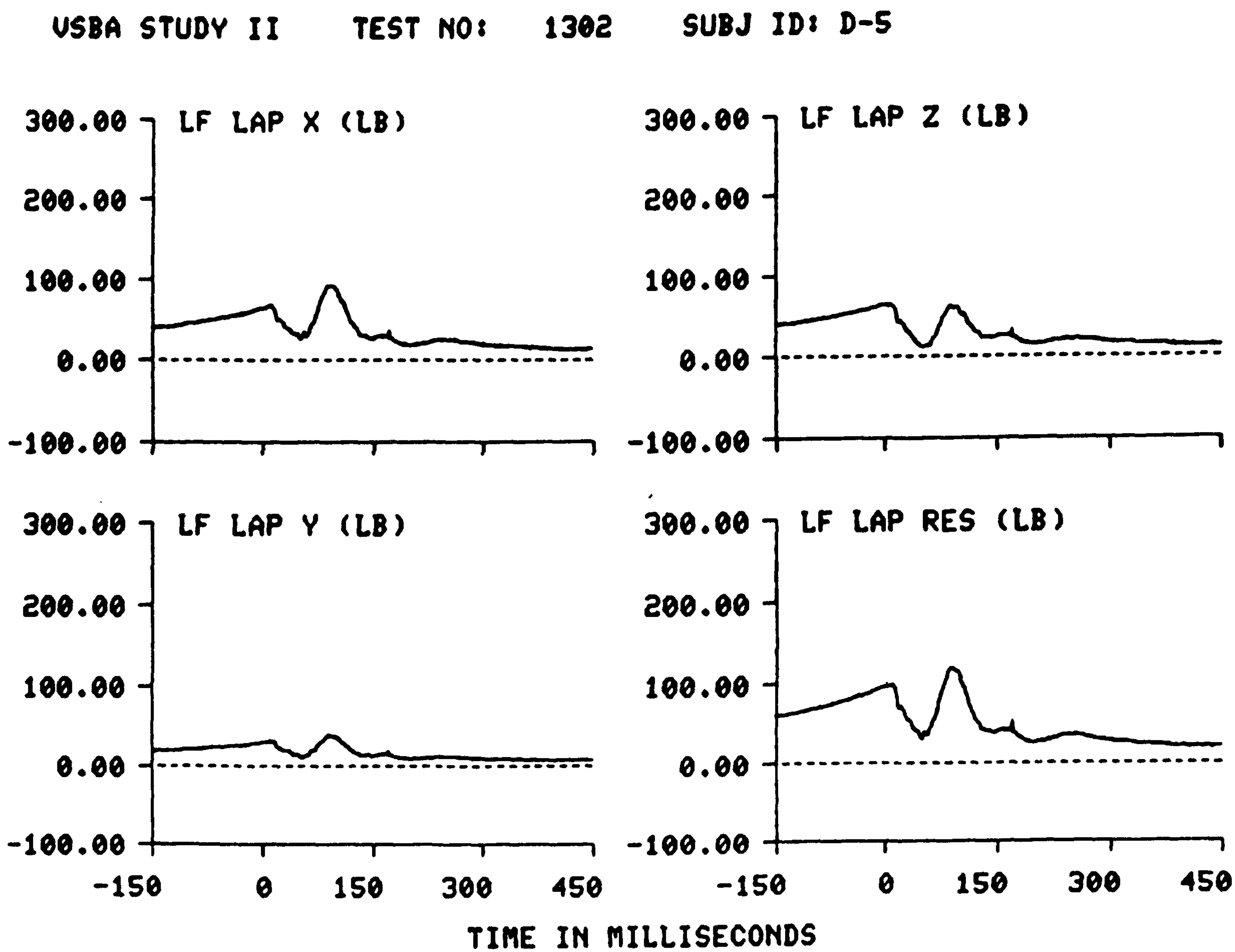
VSBA STUDY II TEST NO: 1302 SUBJ ID: D-5

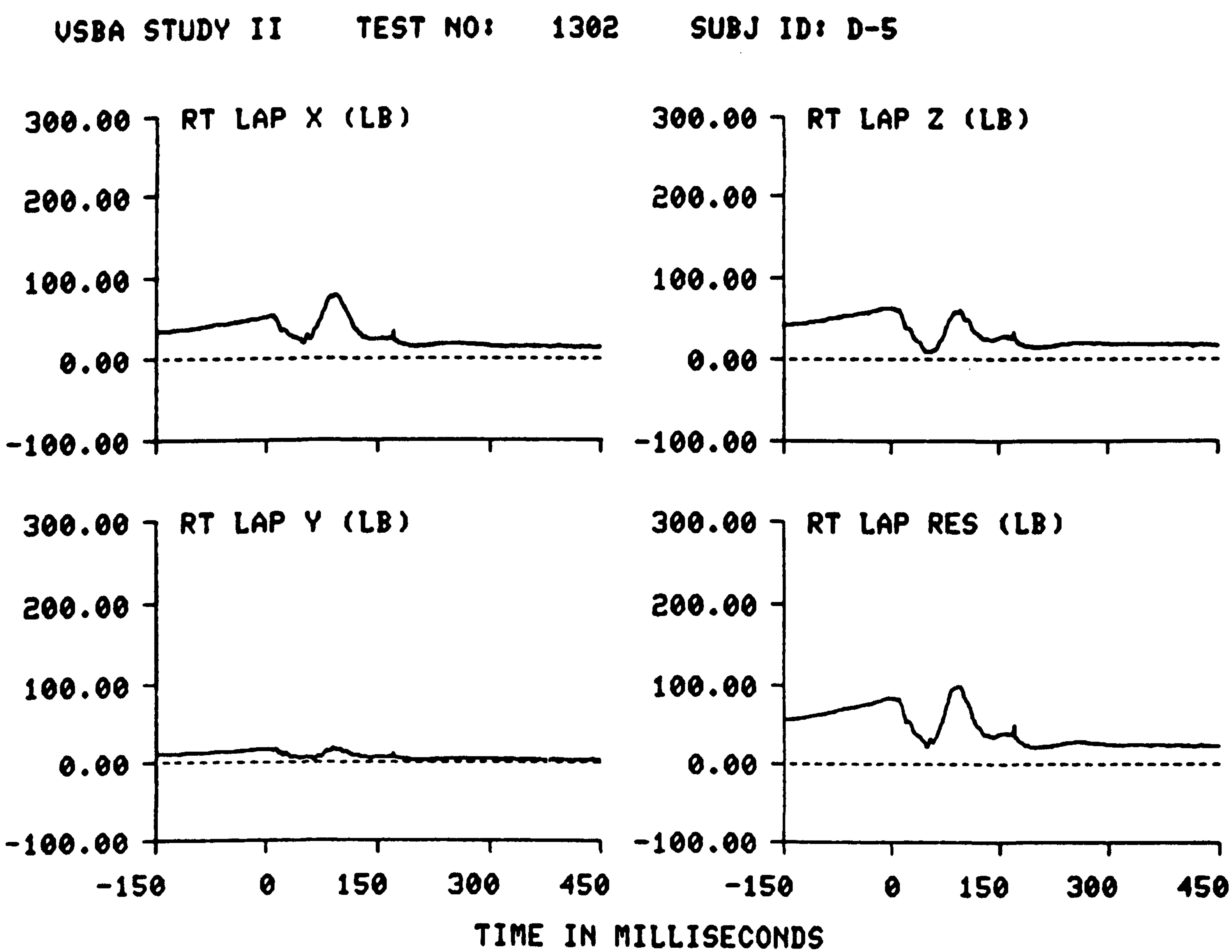


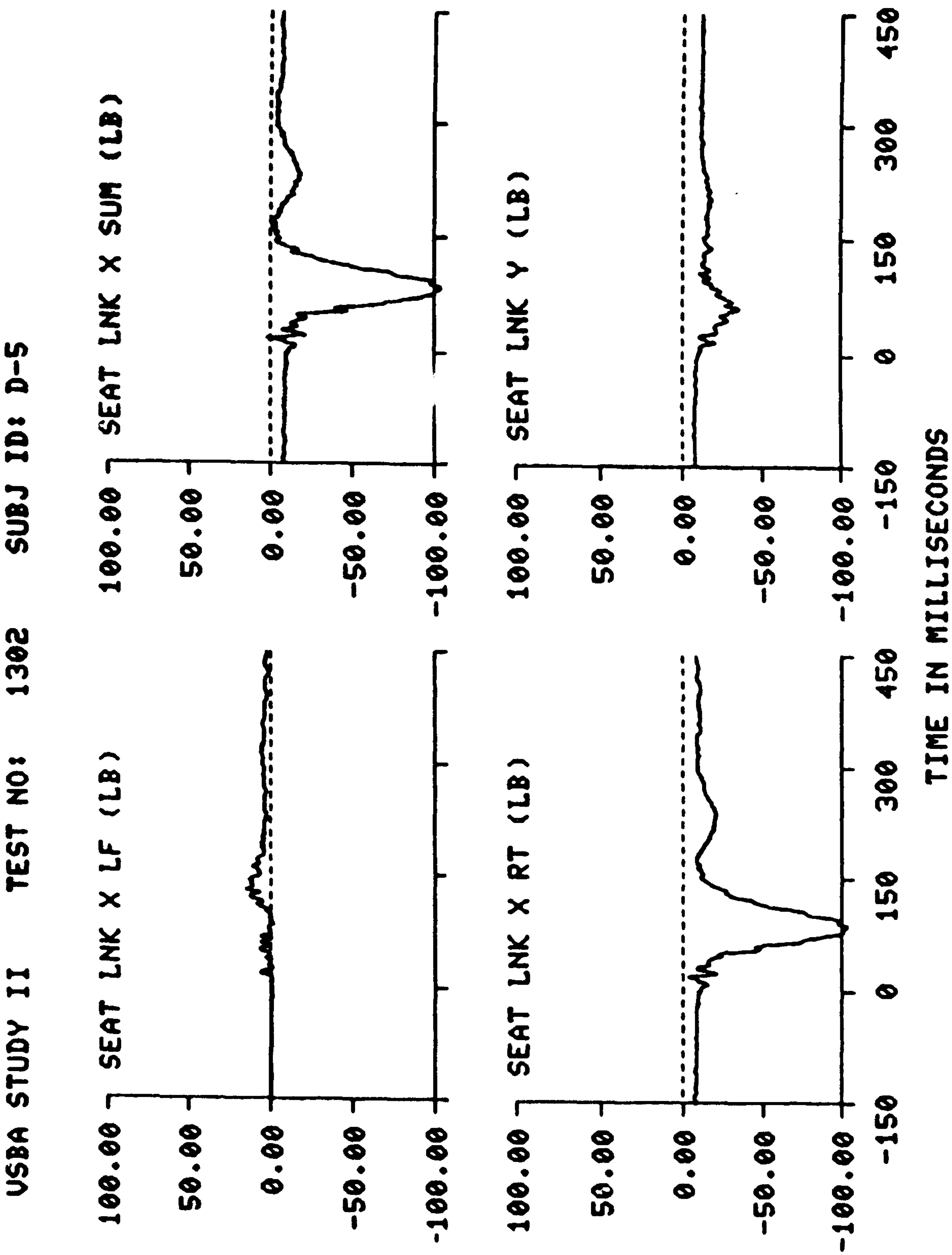
USBA STUDY II TEST NO: 1302 SUBJ ID: D-5

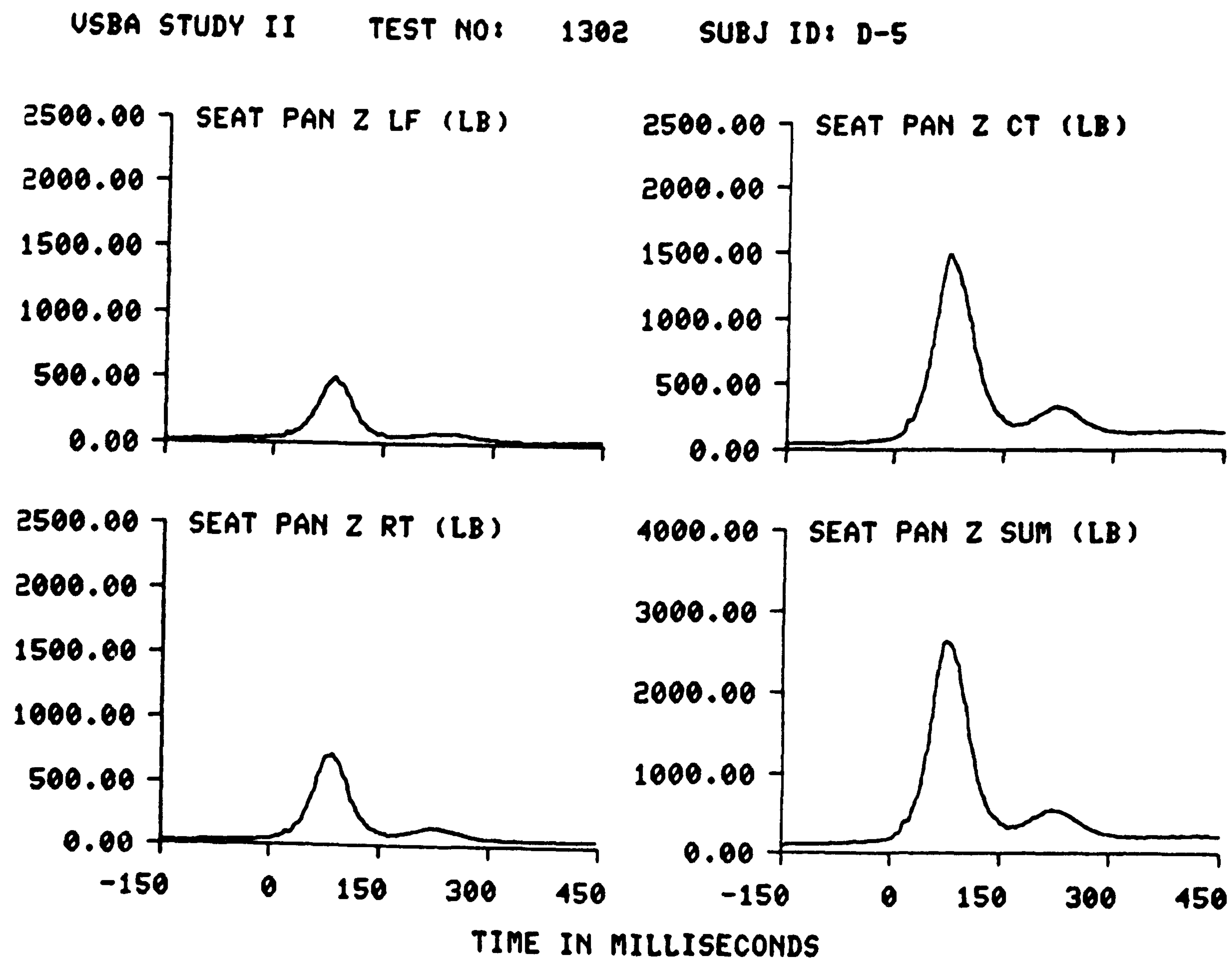



USBA STUDY II TEST NO: 1302 SUBJ ID: D-5
SHOULDER X (LB)
SHOULDER Z (LB)
SHOULDER Y (LB)
SHOULDER RES (LB)
300.00
200.00
100.00
0.00
-100.00
-150
0
150
300
450
TIME IN MILLISECONDS

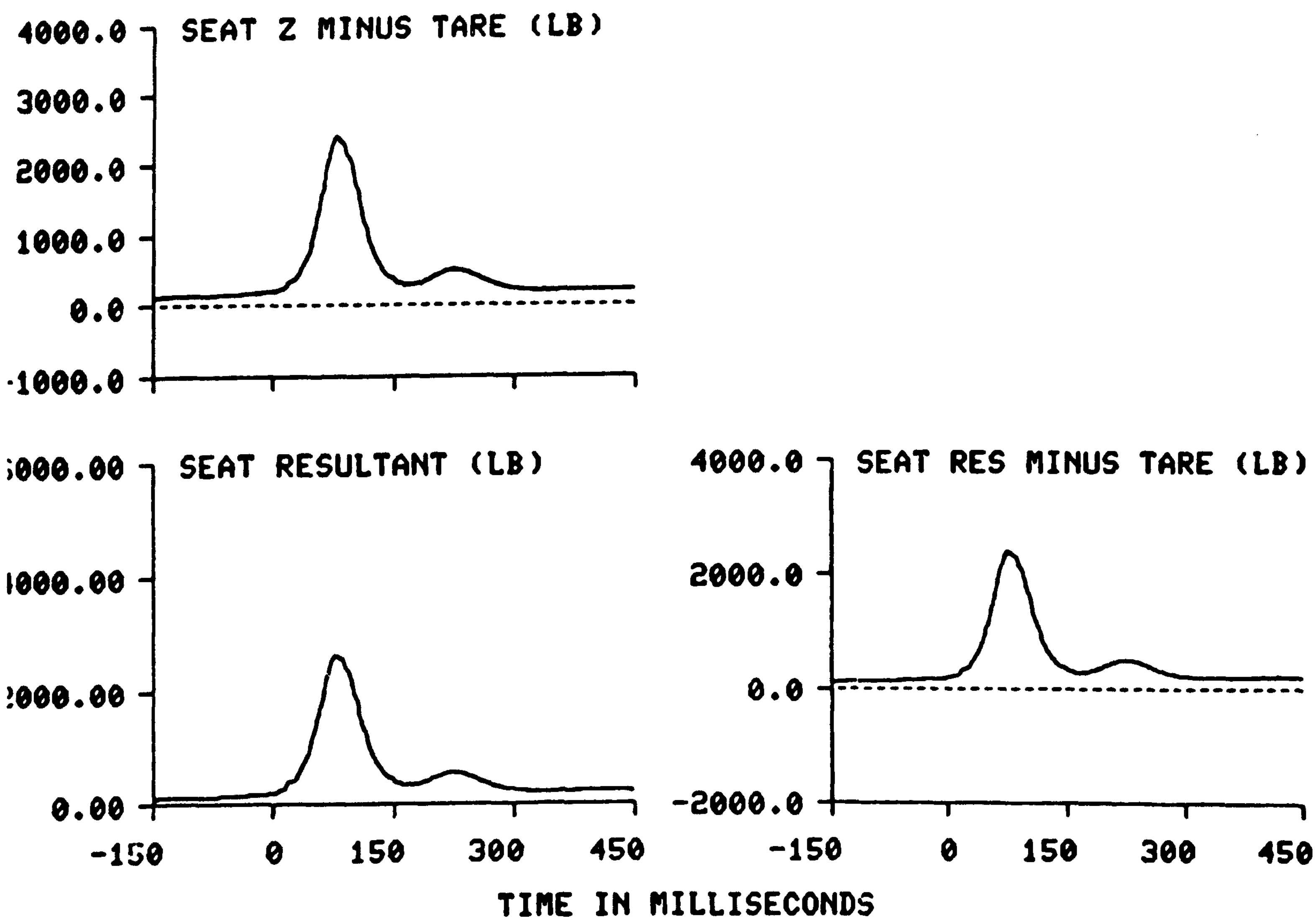

USBA STUDY II TEST NO: 1302 SUBJ ID: D-5
LF LAP X (LB)
LF LAP Z (LB)
LF LAP Y (LB)
LF LAP RES (LB)
300.00
200.00
100.00
0.00
-100.00
-150
0
150
300
450
TIME IN MILLISECONDS


USBA STUDY II TEST NO: 1302 SUBJ ID: D-5
RT LAP X (LB)
RT LAP Z (LB)
RT LAP Y (LB)
RT LAP RES (LB)
300.00
200.00
100.00
0.00
-100.00
-150
0
150
300
450
TIME IN MILLISECONDS


USBA STUDY II
TEST NO: 1302
SUBJ ID: D-5
SEAT LNK X LF (LB)
SEAT LNK X SUM (LB)
SEAT LNK X RT (LB)
SEAT LNK Y (LB)
100.00
50.00
0.00
-50.00
-100.00
-150
0
150
300
450
TIME IN MILLISECONDS

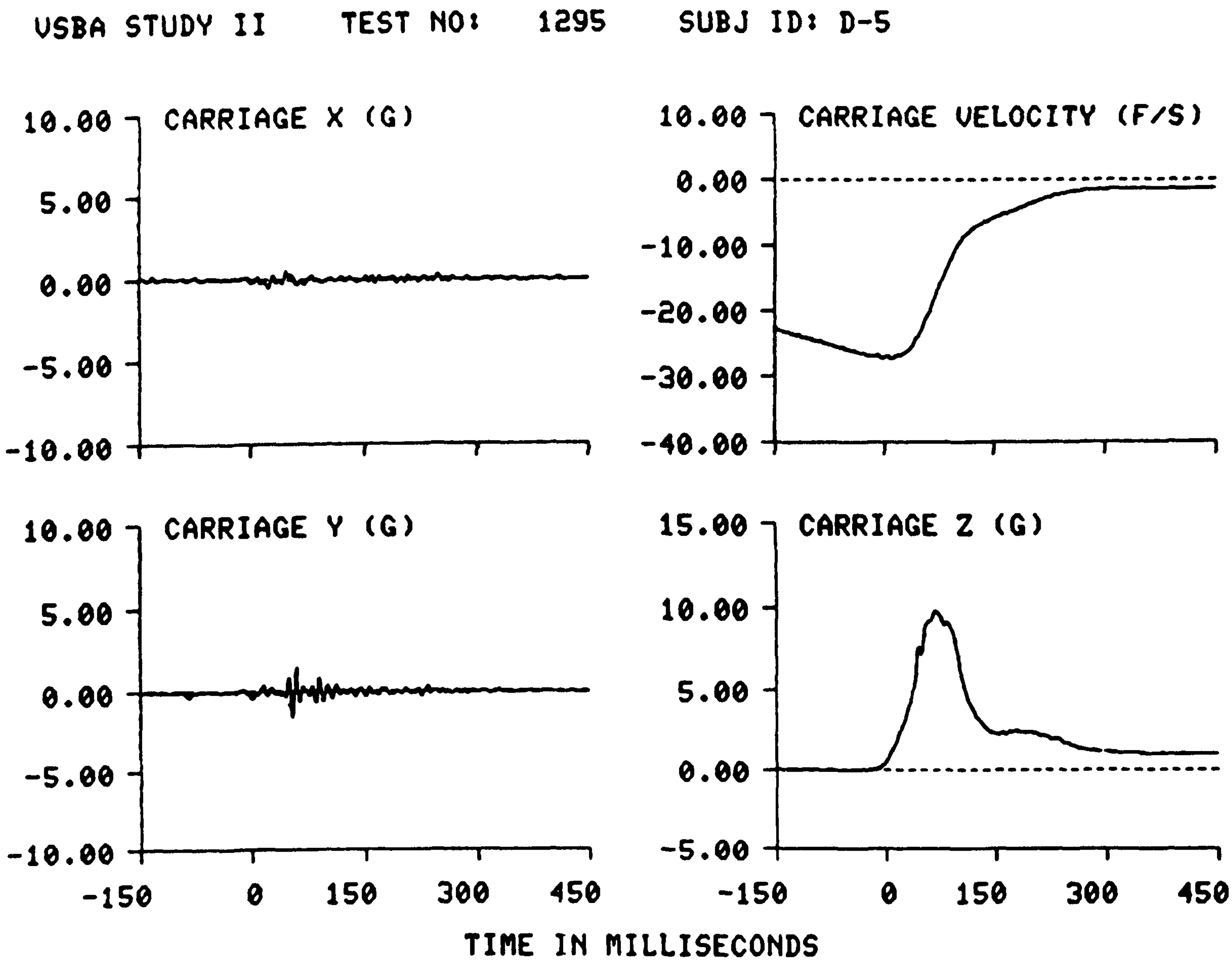

USBA STUDY II TEST NO: 1302 SUBJ ID: D-5
SEAT PAN Z LF (LB)
SEAT PAN Z CT (LB)
SEAT PAN Z RT (LB)
SEAT PAN Z SUM (LB)
2500.00
2000.00
1500.00
1000.00
500.00
0.00
4000.00
3000.00
2000.00
1000.00
-150
0
150
300
450
TIME IN MILLISECONDS

USBA STUDY II TEST NO: 1302 SUBJ ID: D-5



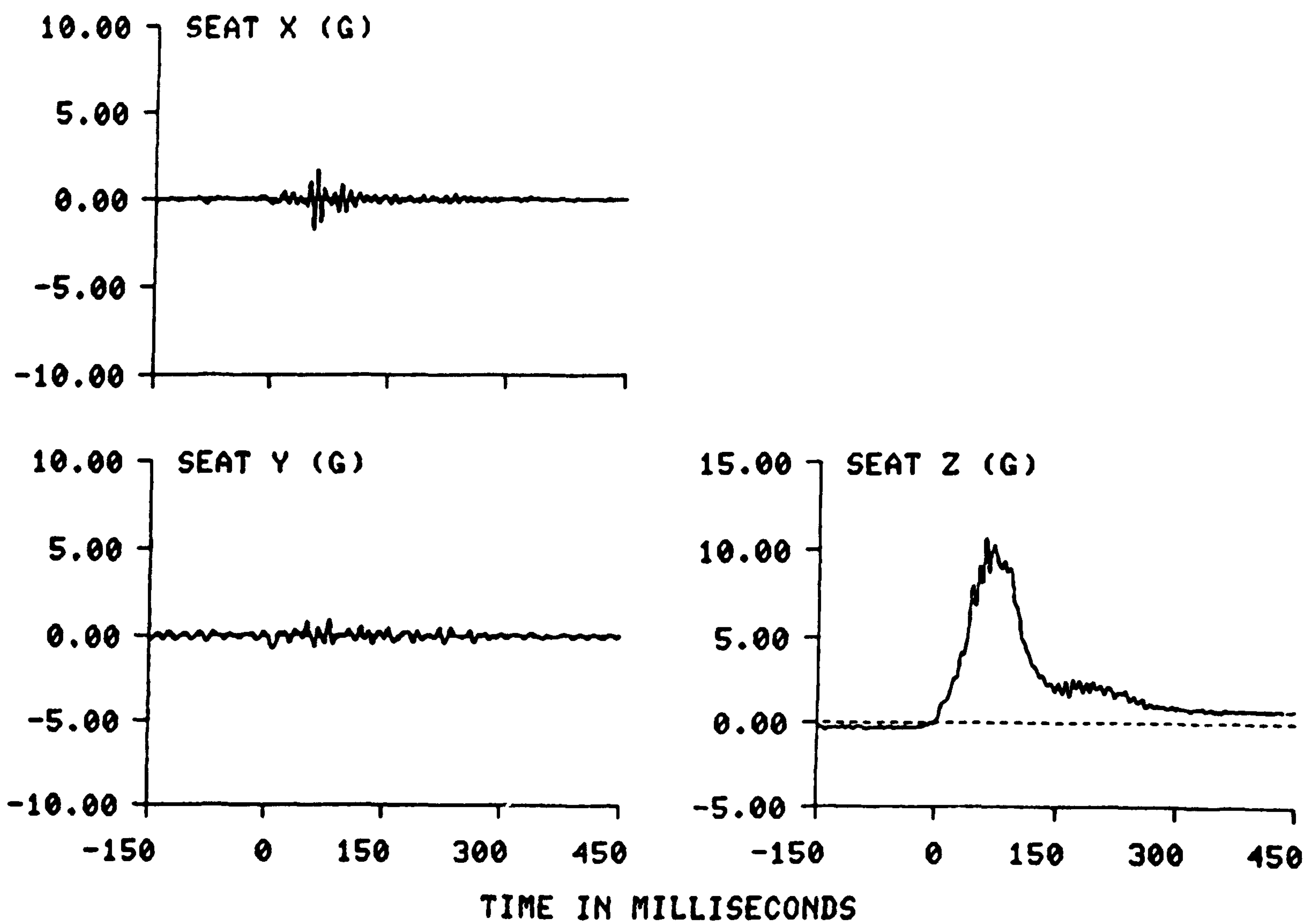
VSBA STUDY II TEST: 1295 SUBJ: D-5 WT: 172.0 NOM G: 10.0 CELL: F

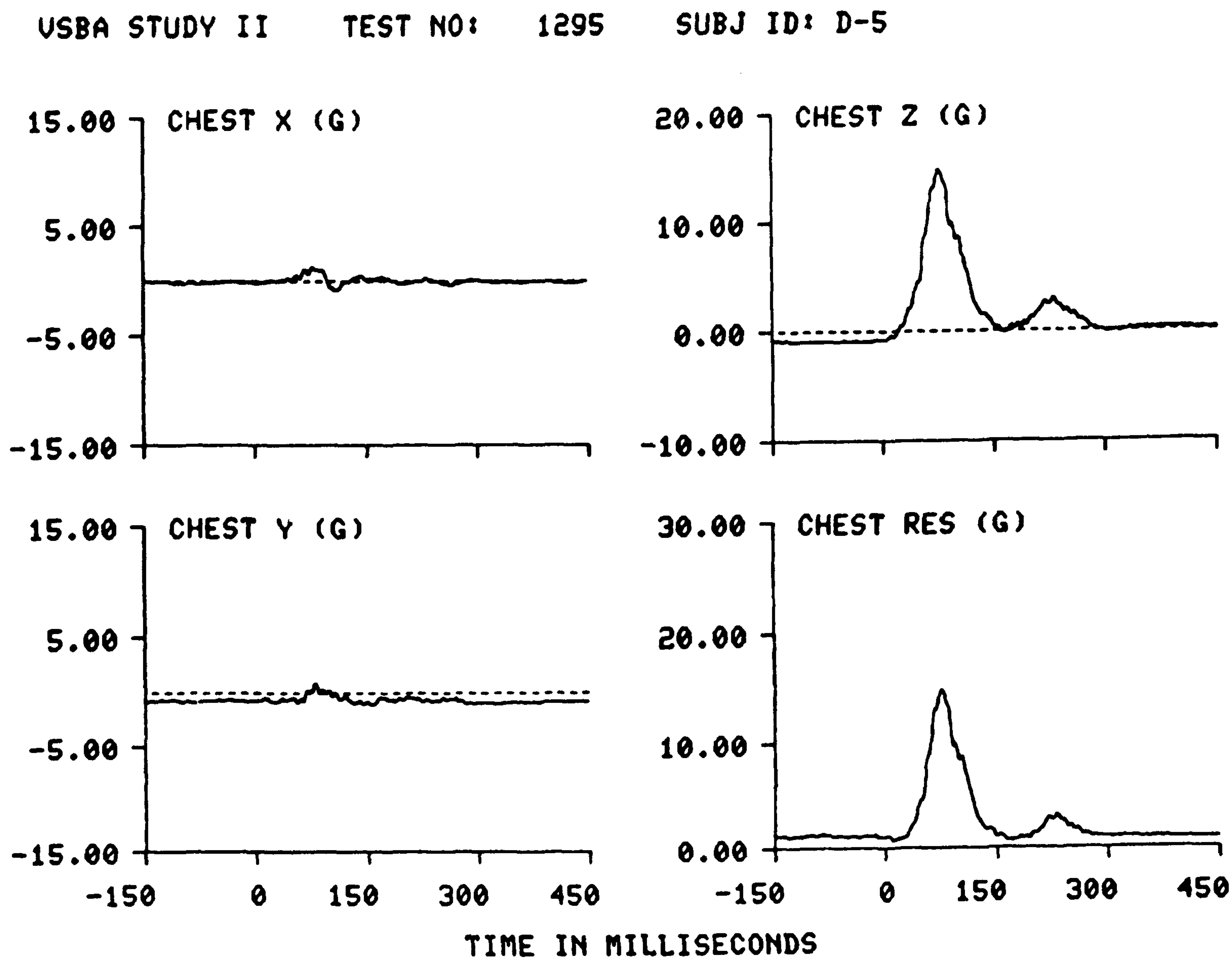
DATA ID	IMMEDIATE PREIMPACT	MAXIMUM VALUE	MINIMUM VALUE	TIME OF MAXIMUM	TIME OF MINIMUM
REFERENCE MARK				-150.	
2.5V EXT PWR		2.50	2.50	0.	10.
10V EXT PWR		10.01	10.00	1.	0.
CARRIAGE ACCELERATION (G)					
X AXIS	0.07	0.53	-0.49	44.	23.
Y AXIS	-0.03	1.44	-1.61	57.	52.
Z AXIS	0.05	9.86	0.50	67.	0.
Z AXIS (SM)	0.07	9.65	0.56	69.	0.
SEAT ACCELERATION (G)					
X AXIS	0.05	1.69	-1.74	56.	52.
Y AXIS	-0.02	0.91	-0.77	79.	8.
Z AXIS	-0.24	10.72	0.03	61.	0.
Z AXIS (SM)	-0.24	9.89	0.11	71.	0.
RY	-8.26	26.72	-33.25	61.	65.
CARRIAGE VELOCITY (F/S)	-26.81	-1.24	-27.40	333.	9.
CHEST ACCELERATION (G)					
X AXIS	-0.06	1.25	-0.78	76.	107.
Y AXIS	-0.74	0.86	-1.08	78.	155.
Z AXIS	-0.83	14.81	-0.77	76.	3.
RESULTANT	1.11	14.88	0.59	76.	170.
NORM RESULTANT	0.12	1.54	0.06	76.	170.
SI		27.63			
RY	5.69	219.60	-304.57	68.	92.
HEAD ACCELERATION (G)					
X AXIS	-0.35	1.95	-3.29	157.	109.
Y AXIS	-0.48	0.19	-1.44	169.	67.
Z AXIS	-0.59	13.60	-1.33	71.	165.
RESULTANT	0.82	13.66	0.34	71.	178.
NORM RESULTANT	0.09	1.42	0.04	71.	178.
SI		22.19			
RY	0.89	161.45	-134.57	73.	164.
THORAX ACCELERATION (G)					
X AXIS	-0.59	0.62	-6.91	162.	78.
Y AXIS	0.17	0.89	-3.13	161.	81.
Z AXIS	-0.31	14.02	-0.45	88.	164.
RESULTANT	0.70	15.14	0.08	88.	167.
NORM RESULTANT	0.07	1.57	0.01	88.	167.
SHOULDER LOADS (LB)					
X AXIS	87.28	125.73	33.98	61.	301.
Y AXIS	-2.46	7.69	-3.06	215.	4.
Z AXIS	2.10	38.39	1.63	85.	1.
RESULTANT	87.35	129.74	34.83	61.	301.
LAP LOADS (LB)					
LEFT X AXIS	67.79	87.01	17.29	98.	338.
LEFT Y AXIS	24.48	26.40	8.78	96.	52.
LEFT Z AXIS	59.48	56.56	-1.66	0.	60.
LEFT RESULTANT	93.45	103.13	23.43	98.	362.
RIGHT X AXIS	54.99	77.85	11.25	96.	357.
RIGHT Y AXIS	19.89	23.35	3.30	99.	61.
RIGHT Z AXIS	61.81	59.10	-0.10	0.	61.
RIGHT RESULTANT	85.09	99.01	16.12	97.	57.
SEAT LOADS (LB)					
LEFT LINK X AXIS	-0.87	1.84	-12.01	164.	82.
RIGHT LINK X AXIS	2.08	8.08	-26.26	46.	92.
X AXIS	1.21	8.16	-35.88	49.	93.
CENTER LINK Y AXIS	-2.50	-1.38	-36.83	274.	72.
LEFT PAN Z AXIS	46.76	824.40	36.06	84.	360.
RIGHT PAN Z AXIS	37.75	594.42	30.84	84.	325.
CENTER PAN Z AXIS	100.21	1437.98	114.25	72.	0.
Z AXIS SUM	184.72	2565.48	189.71	78.	320.
Z AXIS MINUS TARE	219.70	2337.99	196.25	78.	322.
RESULTANT	184.75	2565.76	189.71	78.	320.
RESULTANT MINUS TARE	219.72	2338.30	196.25	78.	322.

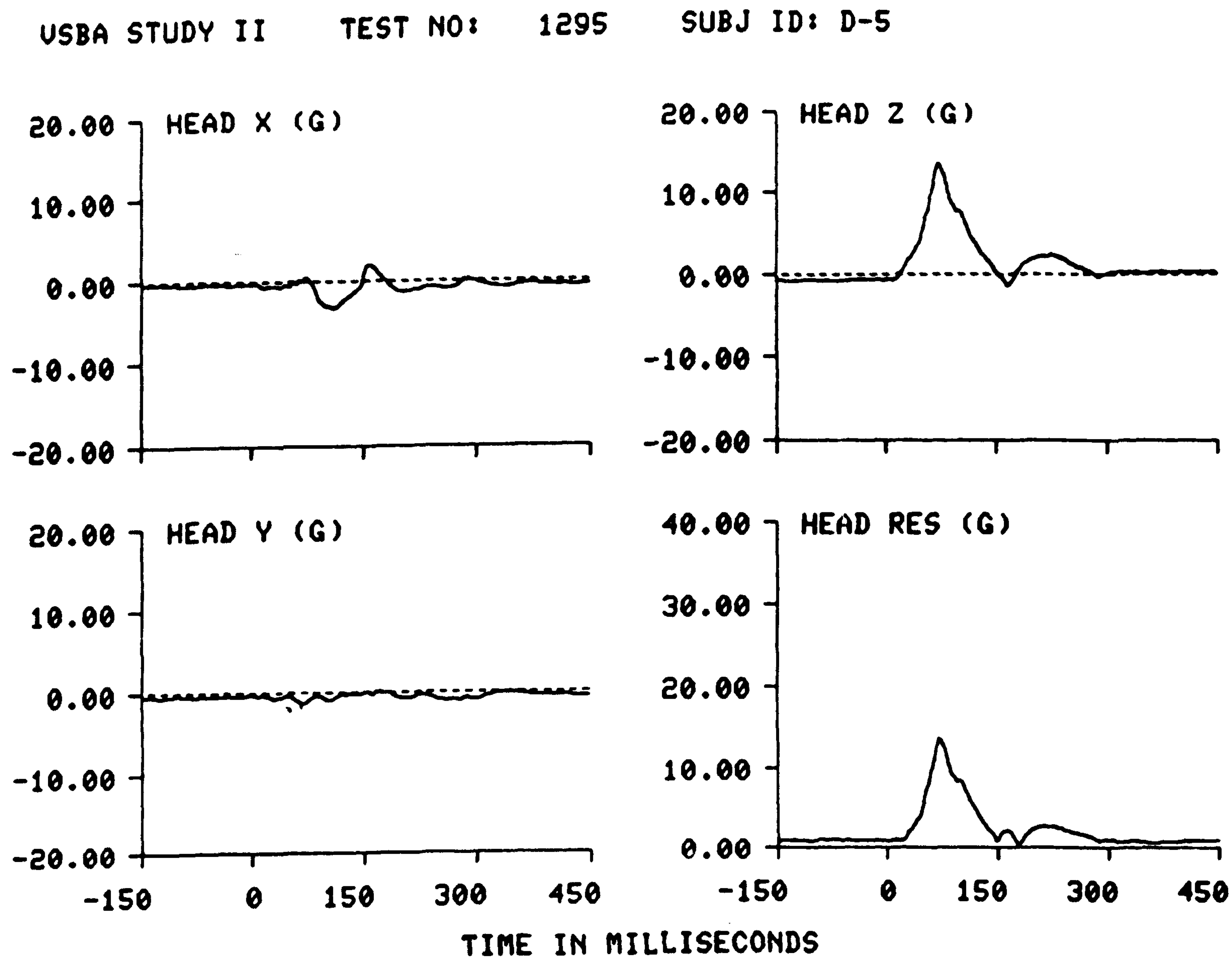


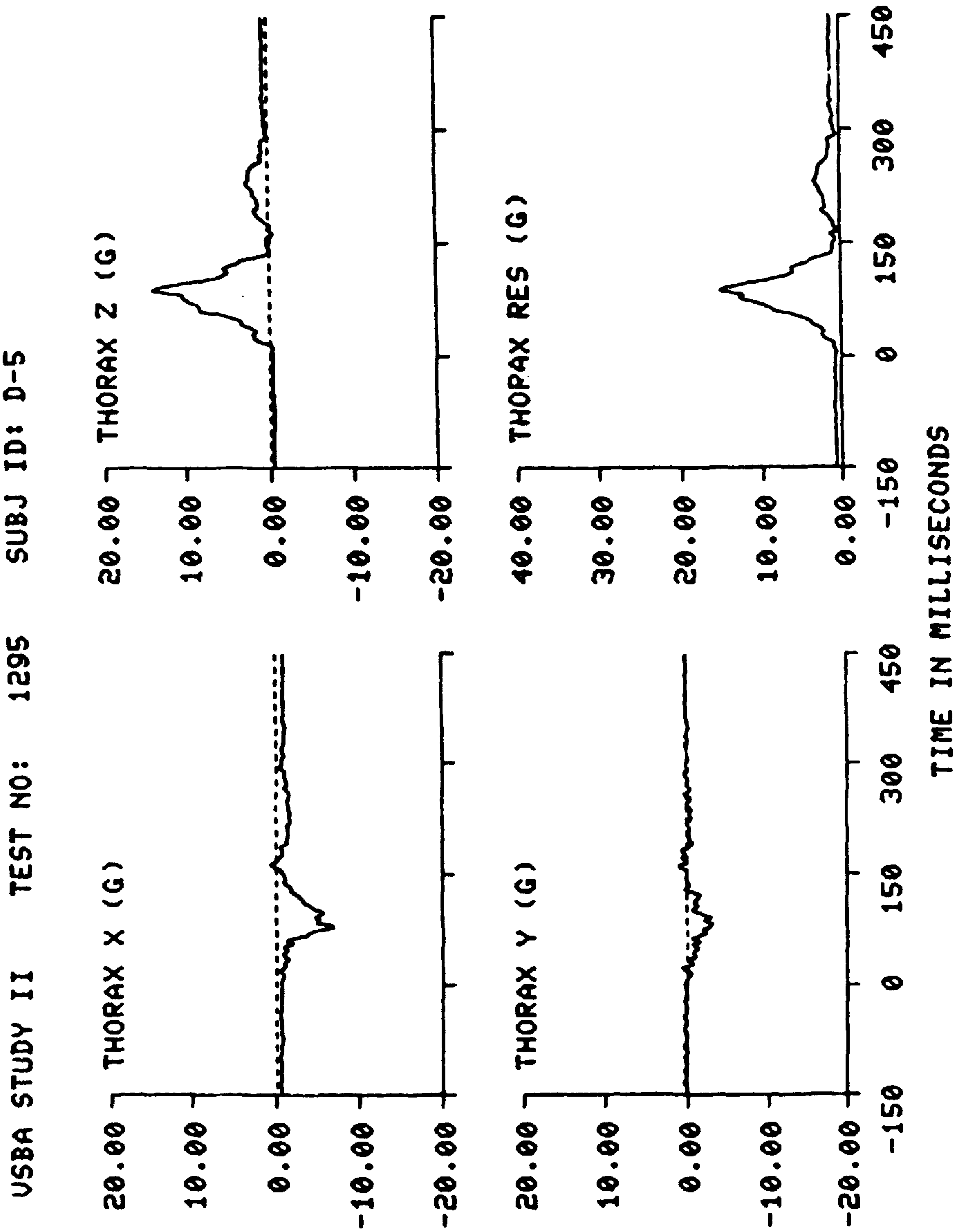
USBA STUDY II TEST NO: 1295 SUBJ ID: D-5
CARRIAGE X (G)
10.00
5.00
0.00
-5.00
-10.00
CARRIAGE VELOCITY (F/S)
10.00
0.00
-10.00
-20.00
-30.00
-40.00
CARRIAGE Y (G)
10.00
5.00
0.00
-5.00
-10.00
CARRIAGE Z (G)
15.00
10.00
5.00
0.00
-5.00
-150
0
150
300
450
TIME IN MILLISECONDS

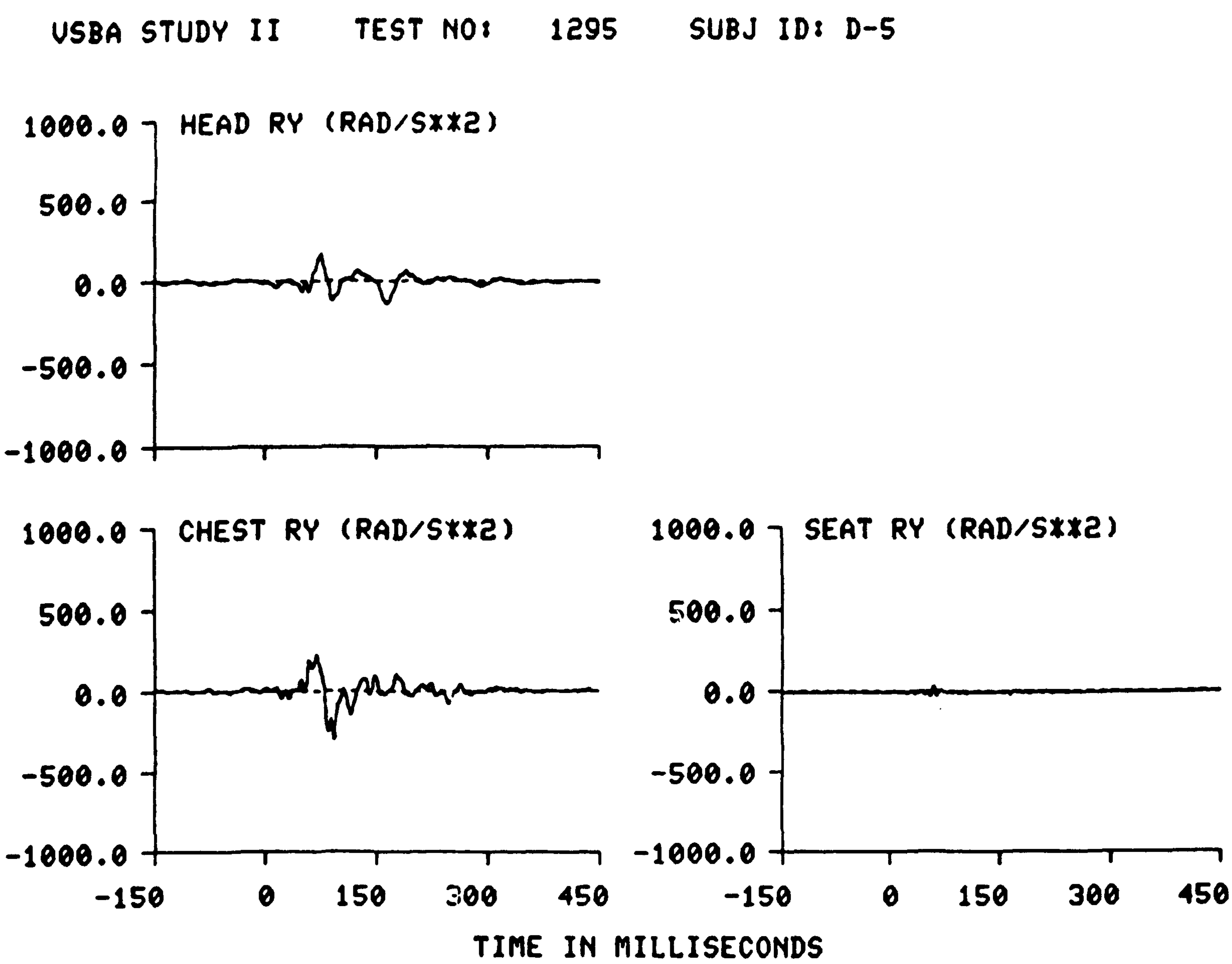
USBA STUDY II TEST NO: 1295 SUBJ ID: D-5




USBA STUDY II TEST NO: 1295 SUBJ ID: D-5
CHEST X (G)
15.00
5.00
-5.00
-15.00
CHEST Z (G)
20.00
10.00
0.00
-10.00
CHEST Y (G)
15.00
5.00
-5.00
-15.00
CHEST RES (G)
30.00
20.00
10.00
0.00
-150
0
150
300
450
TIME IN MILLISECONDS

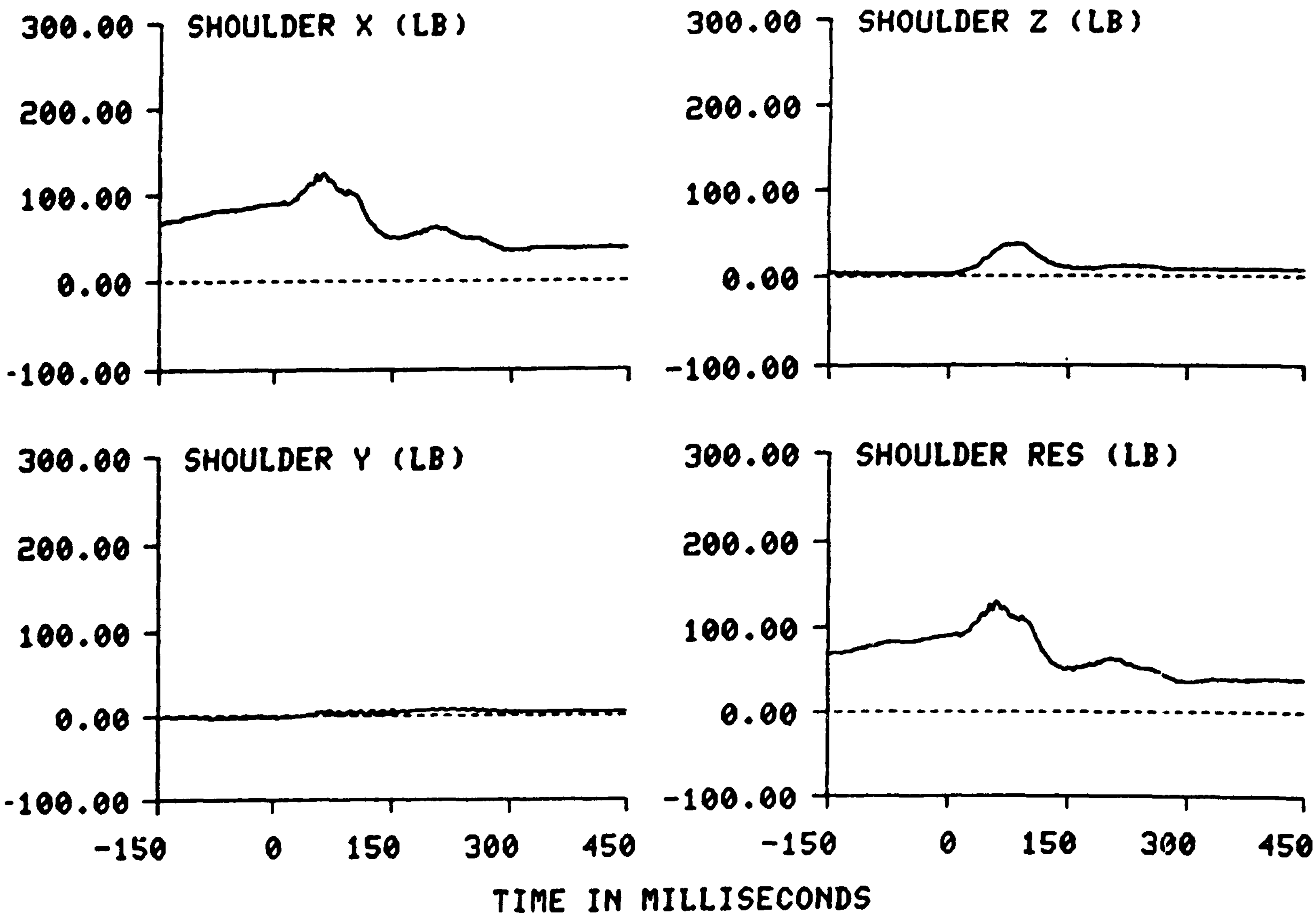

USBA STUDY II TEST NO: 1295 SUBJ ID: D-5
HEAD X (G)
HEAD Z (G)
HEAD Y (G)
HEAD RES (G)
20.00
10.00
0.00
-10.00
-20.00
40.00
30.00
-150
0
150
300
450
TIME IN MILLISECONDS


USBA STUDY II TEST NO: 1295 SUBJ ID: D-5
THORAX X (G)
THORAX Y (G)
THORAX Z (G)
THORAX RES (G)
20.00
10.00
0.00
-10.00
-20.00
40.00
30.00
20.00
10.00
0.00
-150
0
150
300
450
TIME IN MILLISECONDS

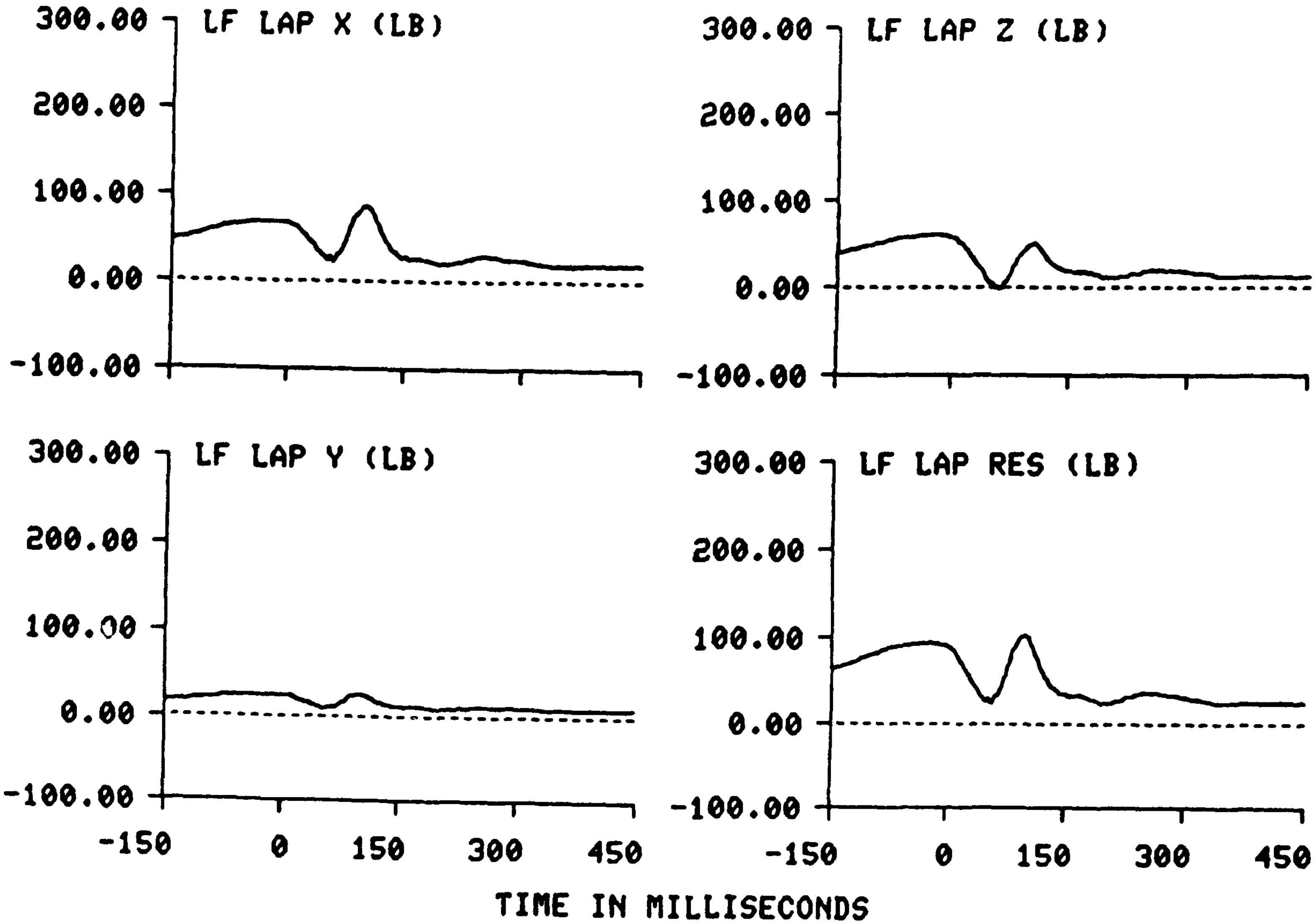


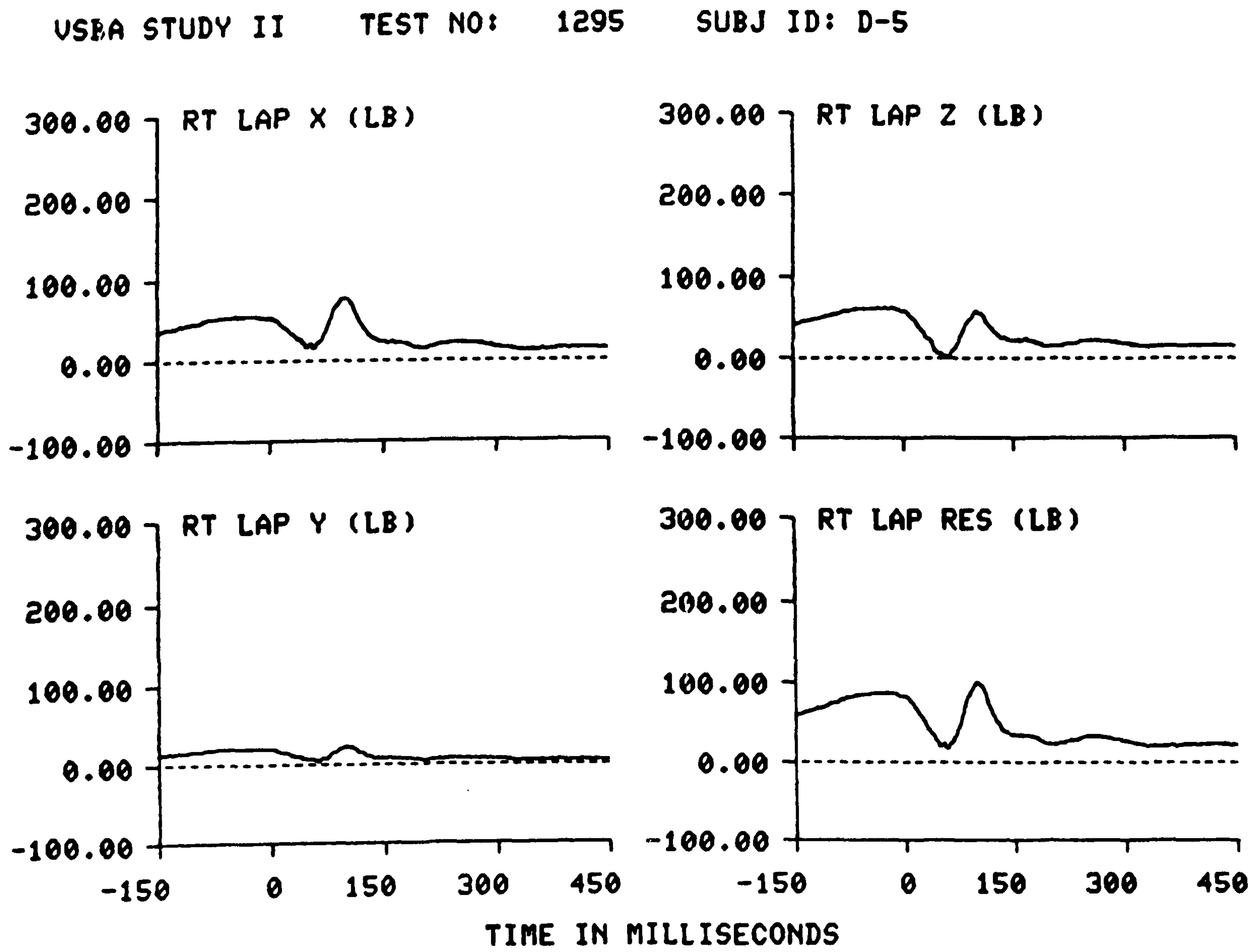
USBA STUDY II TEST NO: 1295 SUBJ ID: D-5
HEAD RY (RAD/S**2)
CHEST RY (RAD/S**2)
SEAT RY (RAD/S**2)
1000.0
500.0
0.0
-500.0
-1000.0
-150
0
150
300
450
TIME IN MILLISECONDS

USBA STUDY II TEST NO: 1295 SUBJ ID: D-5

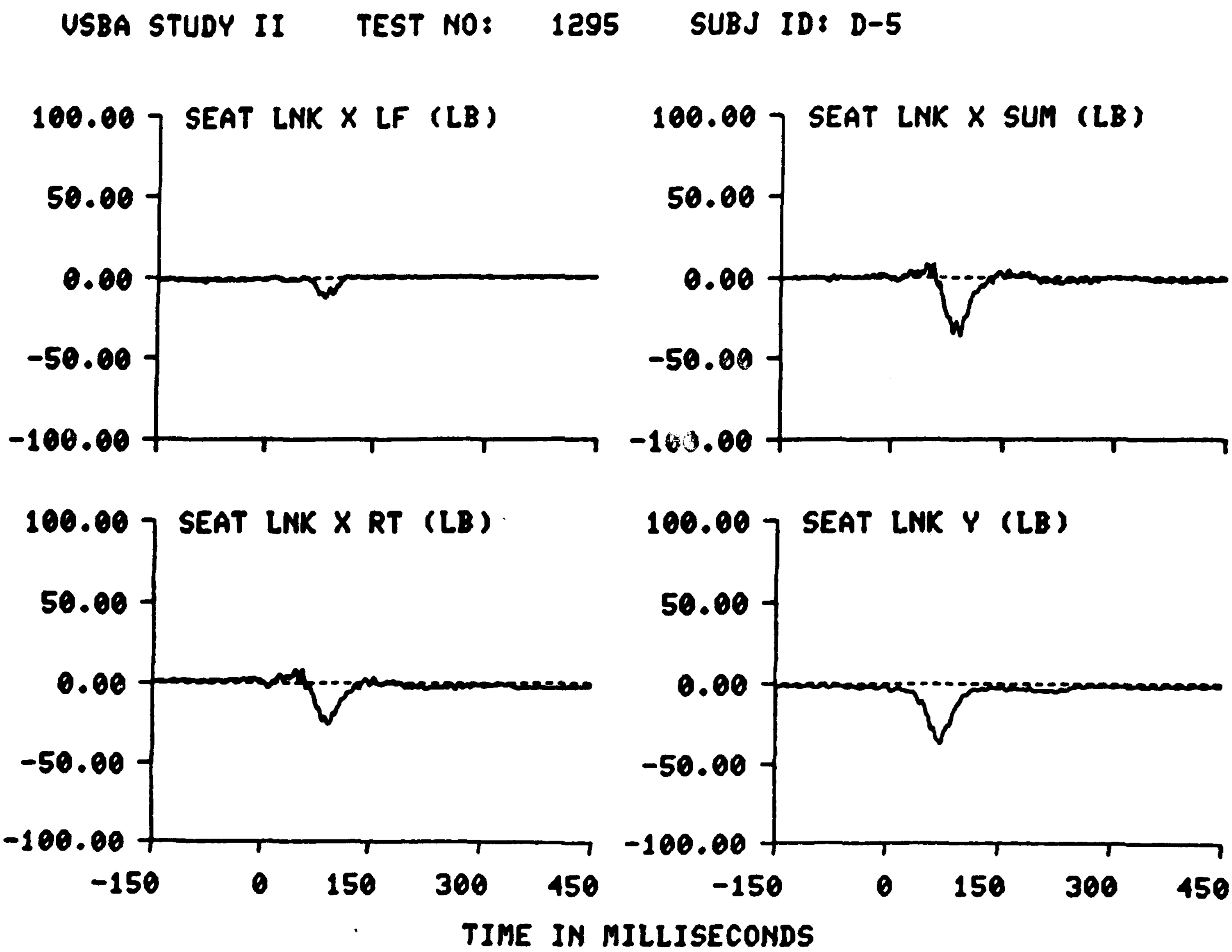


VSBA STUDY II TEST NO: 1295 SUBJ ID: D-5



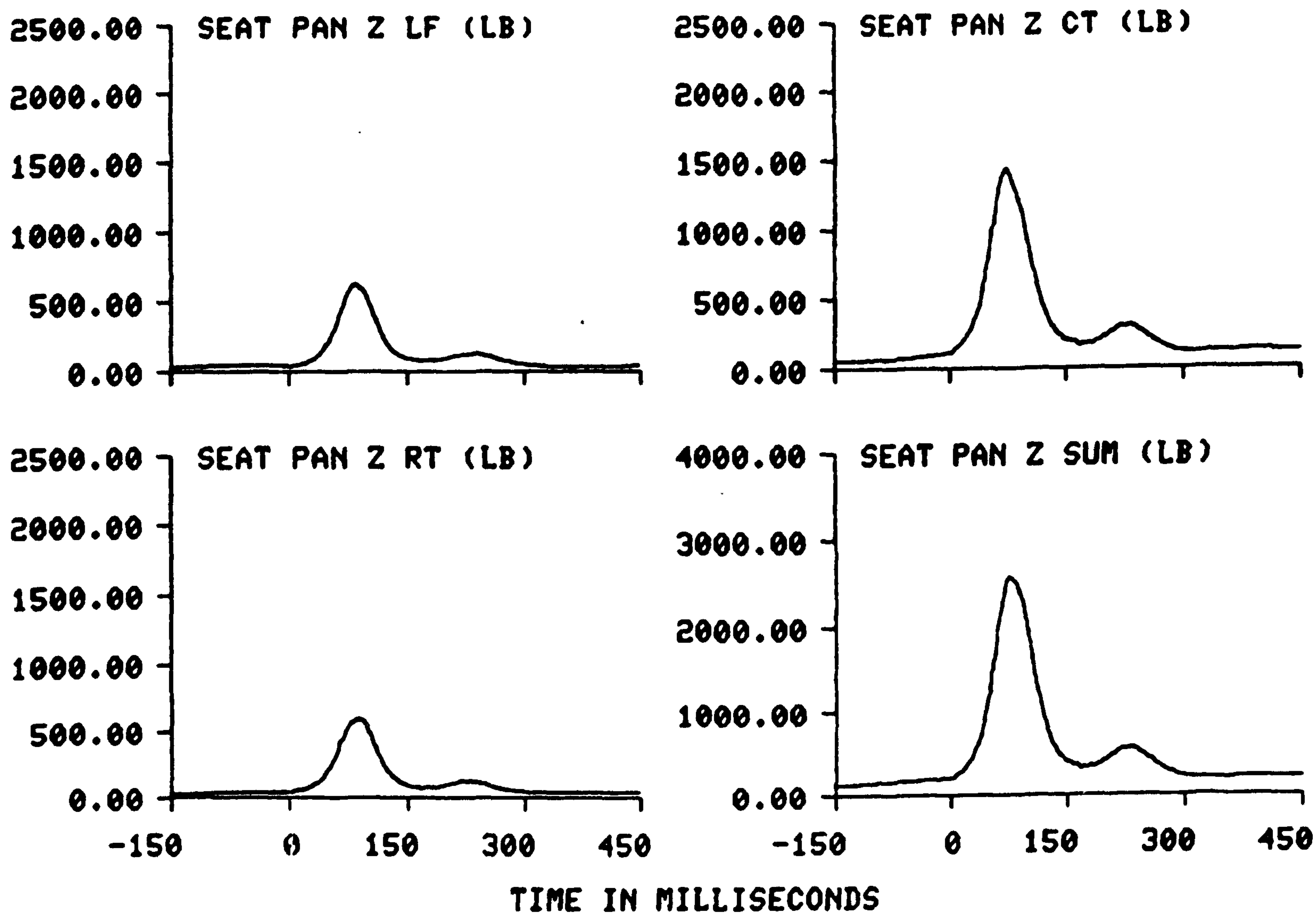


USAA STUDY II TEST NO: 1295 SUBJ ID: D-5
RT LAP X (LB)
RT LAP Z (LB)
RT LAP Y (LB)
RT LAP RES (LB)
300.00
200.00
100.00
0.00
-100.00
-150
0
150
300
450
TIME IN MILLISECONDS

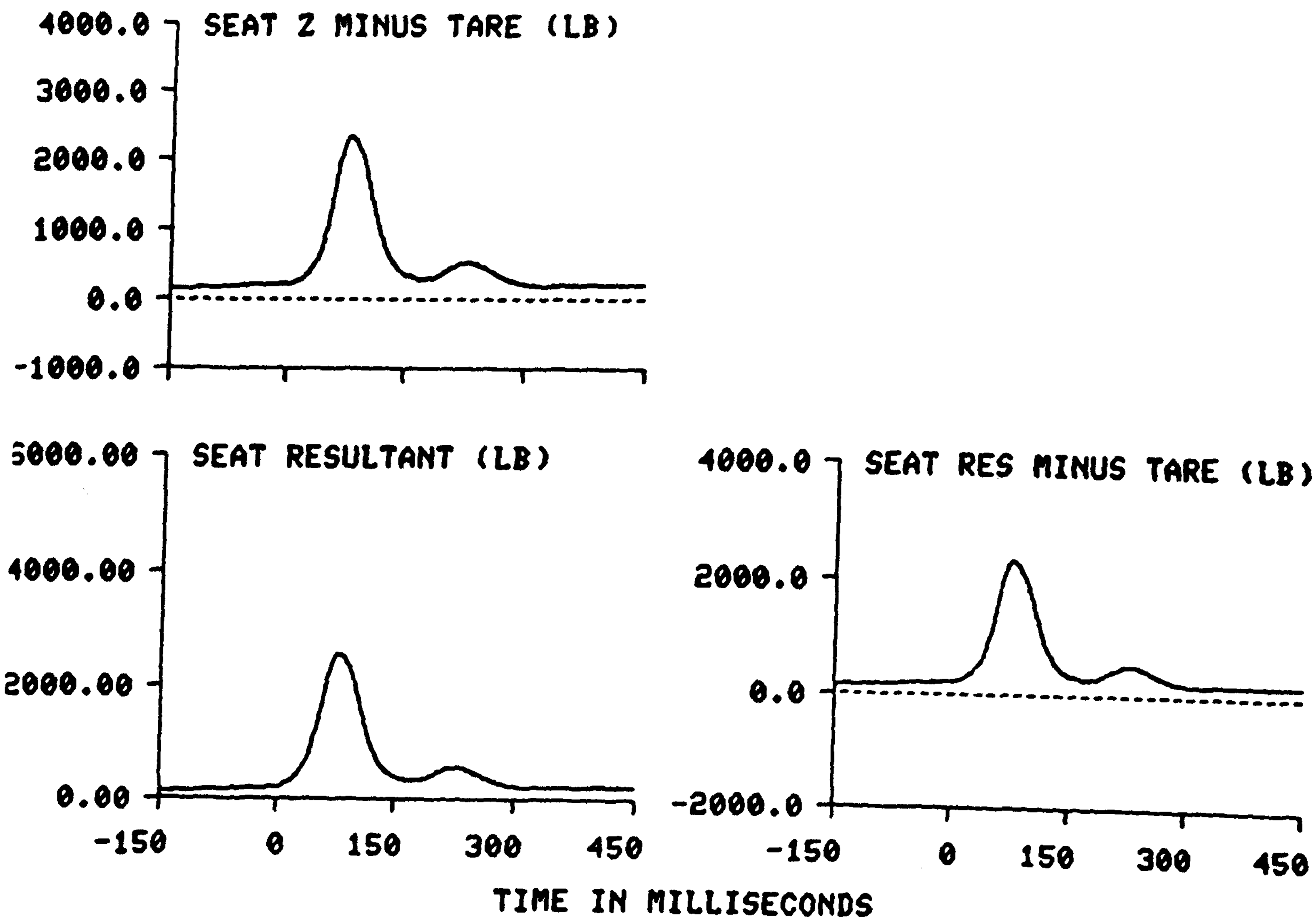


USBA STUDY II TEST NO: 1295 SUBJ ID: D-5
SEAT LNK X LF (LB)
SEAT LNK X SUM (LB)
SEAT LNK X RT (LB)
SEAT LNK Y (LB)
100.00
50.00
0.00
-50.00
-100.00
-150
0
150
300
450
TIME IN MILLISECONDS

VSBA STUDY II TEST NO: 1295 SUBJ ID: D-5



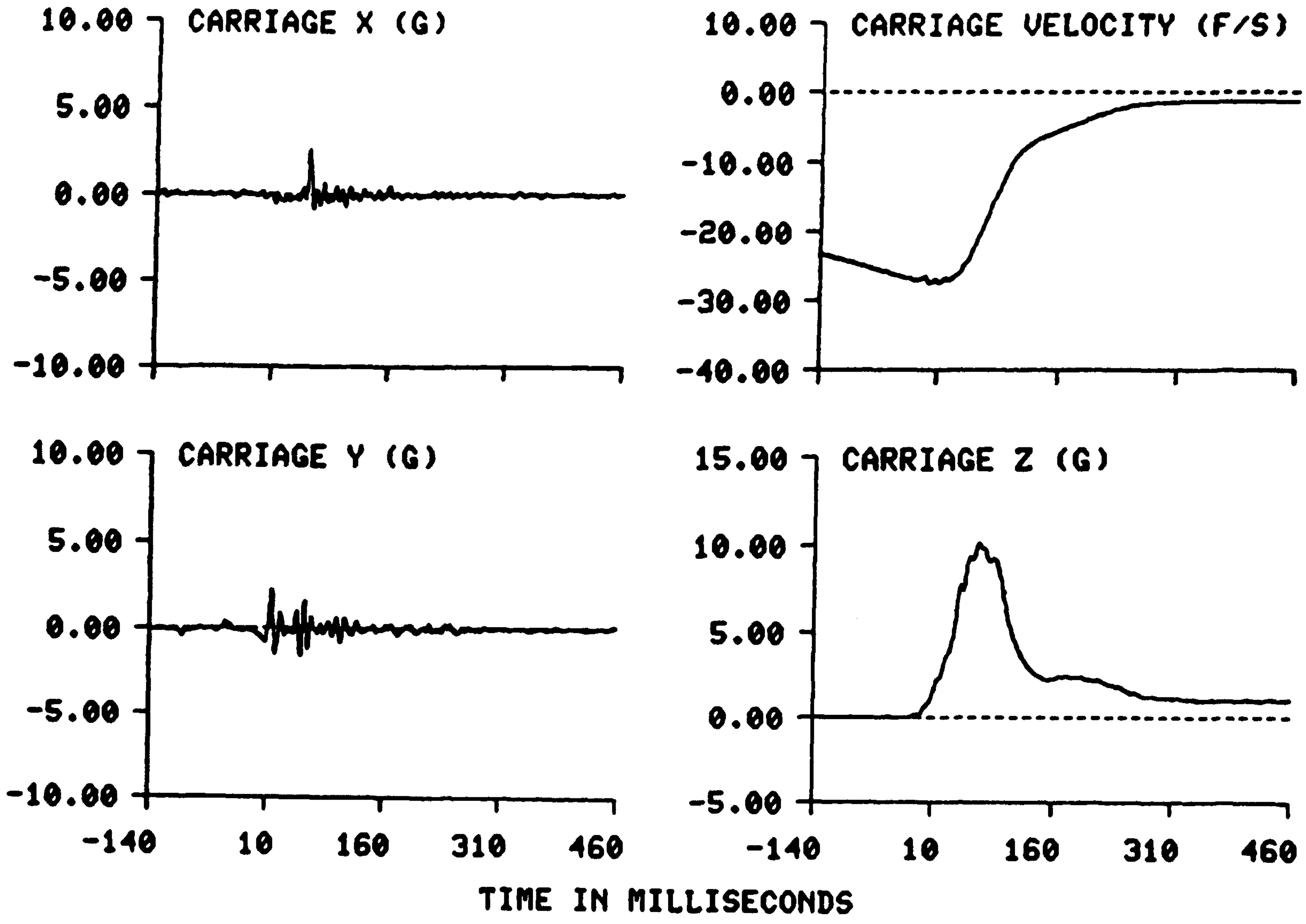
VSBA STUDY II TEST NO: 1295 SUBJ ID: D-5

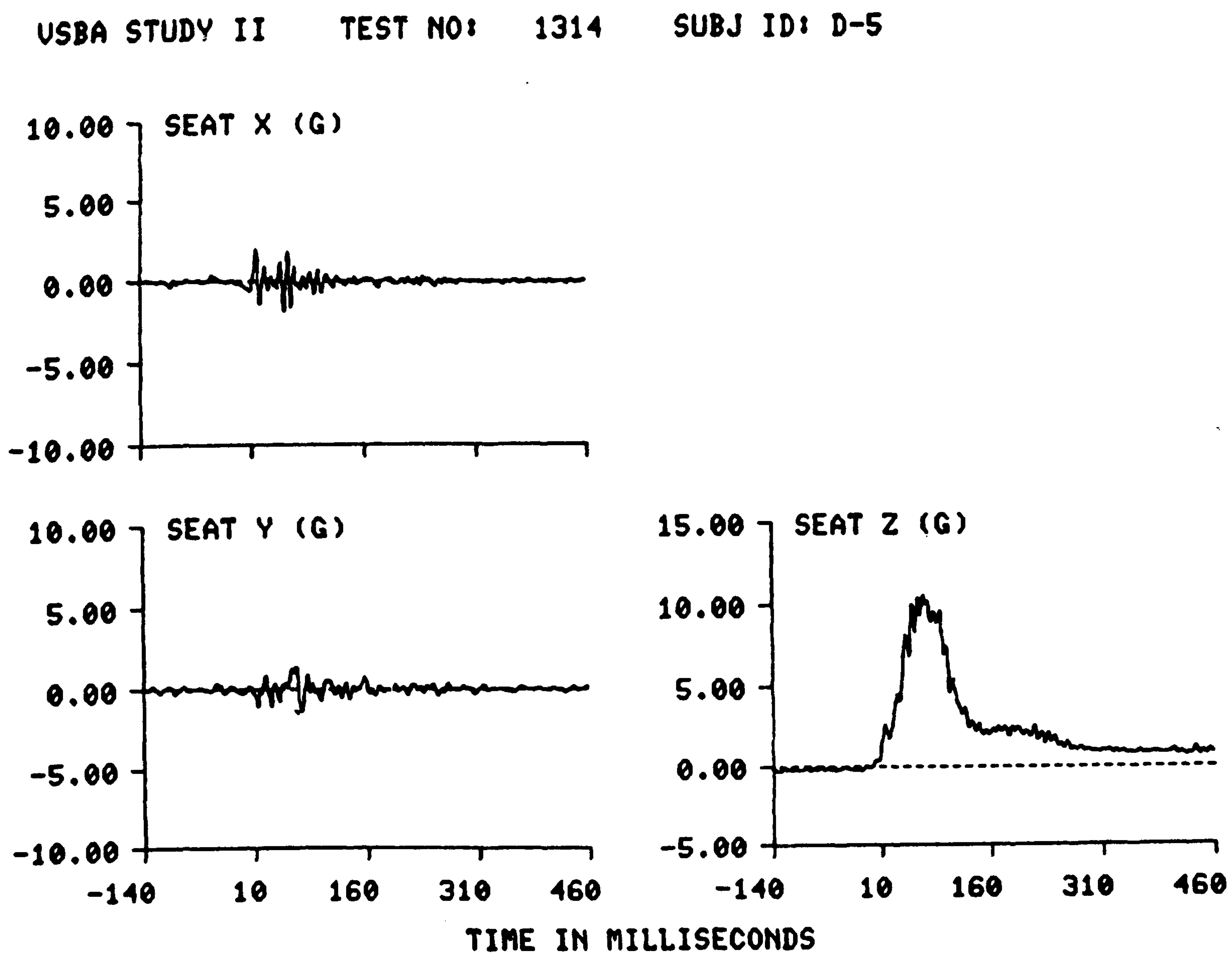


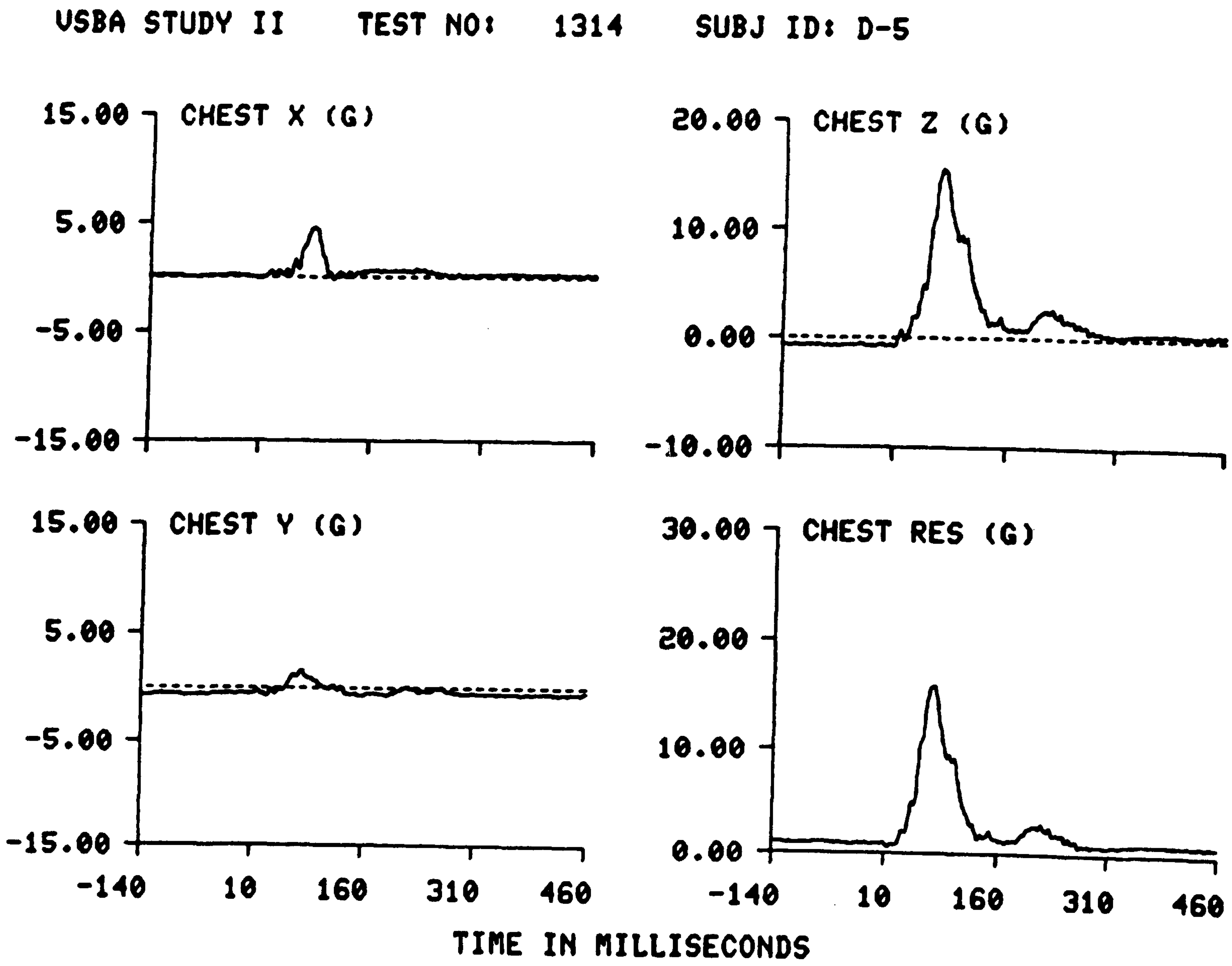
VSBA STUDY II TEST: 1314 SUBJ: D-5 WT: 175.0 NOM G: 10.0 CELL: G

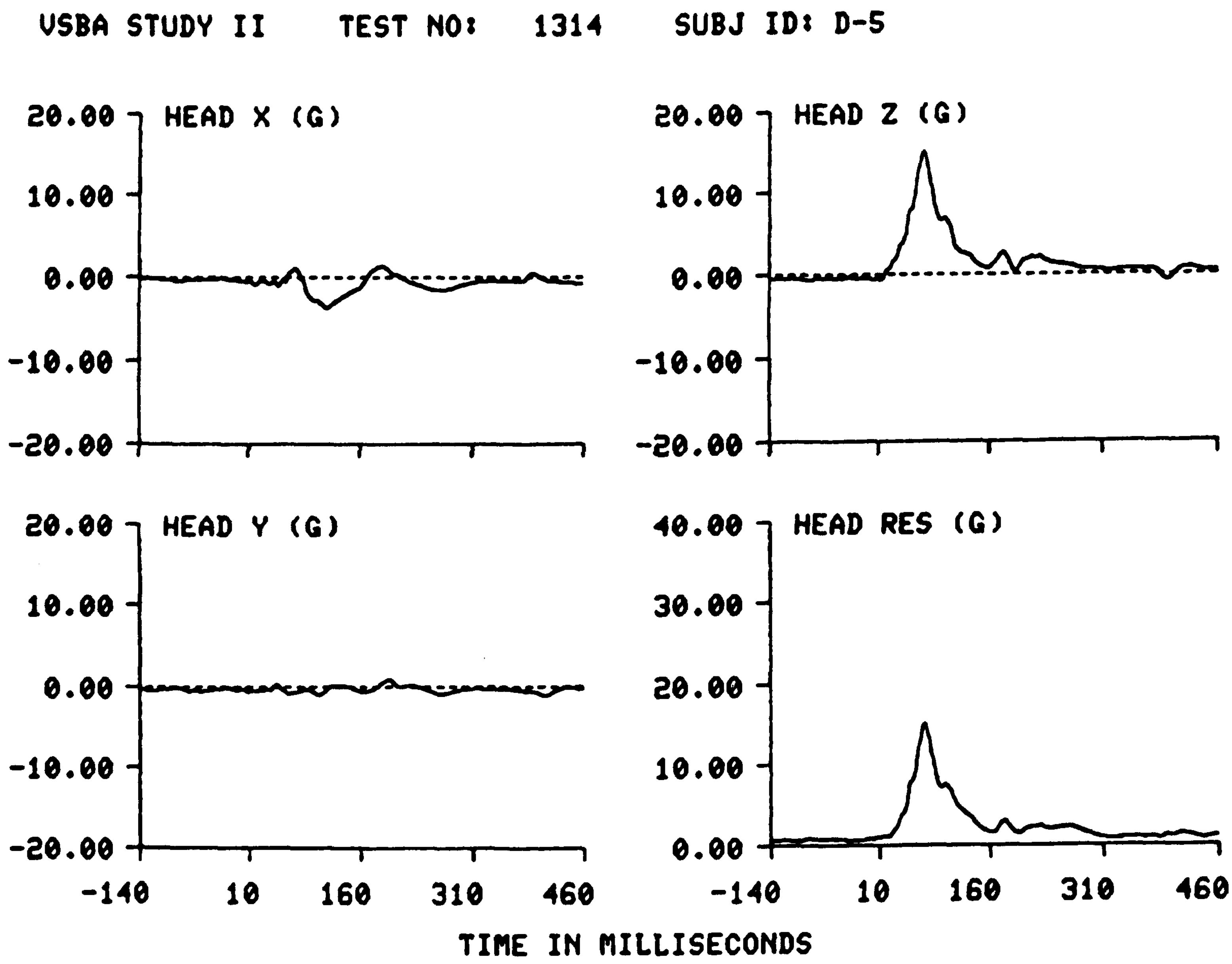
DATA ID	IMMEDIATE PREIMPACT	MAXIMUM VALUE	MINIMUM VALUE	TIME OF MAXIMUM	TIME OF MINIMUM
REFERENCE MARK				-146.	
2.5V EXT PWR		2.50	2.50	36.	0.
10V EXT PWR		10.00	9.99	0.	61.
CARRIAGE ACCELERATION (G)					
X AXIS	0.05	2.81	-0.84	55.	60.
Y AXIS	-0.13	2.25	-1.61	15.	53.
Z AXIS	0.03	10.13	0.48	67.	0.
Z AXIS (SM)	0.05	9.86	0.50	69.	0.
SEAT ACCELERATION (G)					
X AXIS	-0.05	2.05	-1.83	15.	52.
Y AXIS	-0.10	1.38	-1.41	64.	71.
Z AXIS	-0.14	10.50	0.26	69.	0.
Z AXIS (SM)	-0.14	10.15	0.21	70.	0.
RT	-4.55	19.92	-30.05	53.	57.
CARRIAGE VELOCITY (F/S)	-26.84	-1.23	-27.48	355.	10.
CHEST ACCELERATION (G)					
X AXIS	0.15	4.56	-0.22	78.	107.
Y AXIS	-0.53	1.61	-0.85	75.	27.
Z AXIS	-0.58	15.41	-0.75	70.	9.
RESULTANT	0.87	15.84	0.49	75.	15.
NORM RESULTANT	0.09	1.61	0.05	75.	15.
SI		90.91			
RT	6.90	317.22	-414.77	58.	85.
HEAD ACCELERATION (G)					
X AXIS	-0.21	1.37	-3.70	189.	115.
Y AXIS	-0.27	0.92	-1.14	198.	408.
Z AXIS	-0.41	14.95	-0.77	72.	395.
RESULTANT	0.55	15.01	0.67	72.	385.
NORM RESULTANT	0.06	1.52	0.07	72.	385.
SI		23.77			
RT	8.43	284.18	-195.37	75.	92.
THORAX ACCELERATION (G)					
X AXIS	-0.41	0.10	-7.51	161.	93.
Y AXIS	0.52	2.59	-2.02	90.	84.
Z AXIS	-0.40	24.40	-0.47	84.	163.
RESULTANT	0.79	24.55	0.74	84.	14.
NORM RESULTANT	0.08	2.49	0.08	84.	14.
SHOULDER LOADS (LB)					
X AXIS	82.08	148.87	29.44	100.	343.
Y AXIS	8.14	19.23	3.10	84.	345.
Z AXIS	-5.33	34.00	-6.11	90.	0.
RESULTANT	82.66	151.00	29.79	100.	343.
LAP LOADS (LB)					
LEFT X AXIS	54.61	60.33	16.17	6.	457.
LEFT Y AXIS	18.72	21.16	5.31	10.	55.
LEFT Z AXIS	46.64	50.21	-2.09	3.	54.
LEFT RESULTANT	74.22	80.53	20.17	8.	48.
RIGHT X AXIS	50.63	55.93	13.39	100.	346.
RIGHT Y AXIS	13.80	15.02	0.79	2.	70.
RIGHT Z AXIS	52.89	54.73	-1.41	6.	55.
RIGHT RESULTANT	74.51	77.58	17.20	1.	57.
SEAT LOADS (LB)					
LEFT LINK X AXIS	-2.74	15.57	-16.36	15.	62.
RIGHT LINK X AXIS	-2.36	4.87	-46.36	16.	84.
X AXIS	-5.10	19.23	-51.31	16.	75.
CENTER LINK Y AXIS	-0.82	0.65	-22.14	269.	69.
LEFT PAN Z AXIS	33.42	680.43	29.49	85.	0.
RIGHT PAN Z AXIS	47.66	711.94	47.72	84.	311.
CENTER PAN Z AXIS	82.86	1466.18	92.97	72.	0.
Z AXIS SUM	163.94	2716.20	173.27	77.	0.
Z AXIS MINUS TARE	196.23	2475.71	194.27	77.	0.
RESULTANT	164.02	2716.86	173.40	77.	0.
RESULTANT MINUS TARE	196.30	2476.22	194.44	77.	0.

VSBA STUDY II TEST NO: 1314 SUBJ ID: D-5

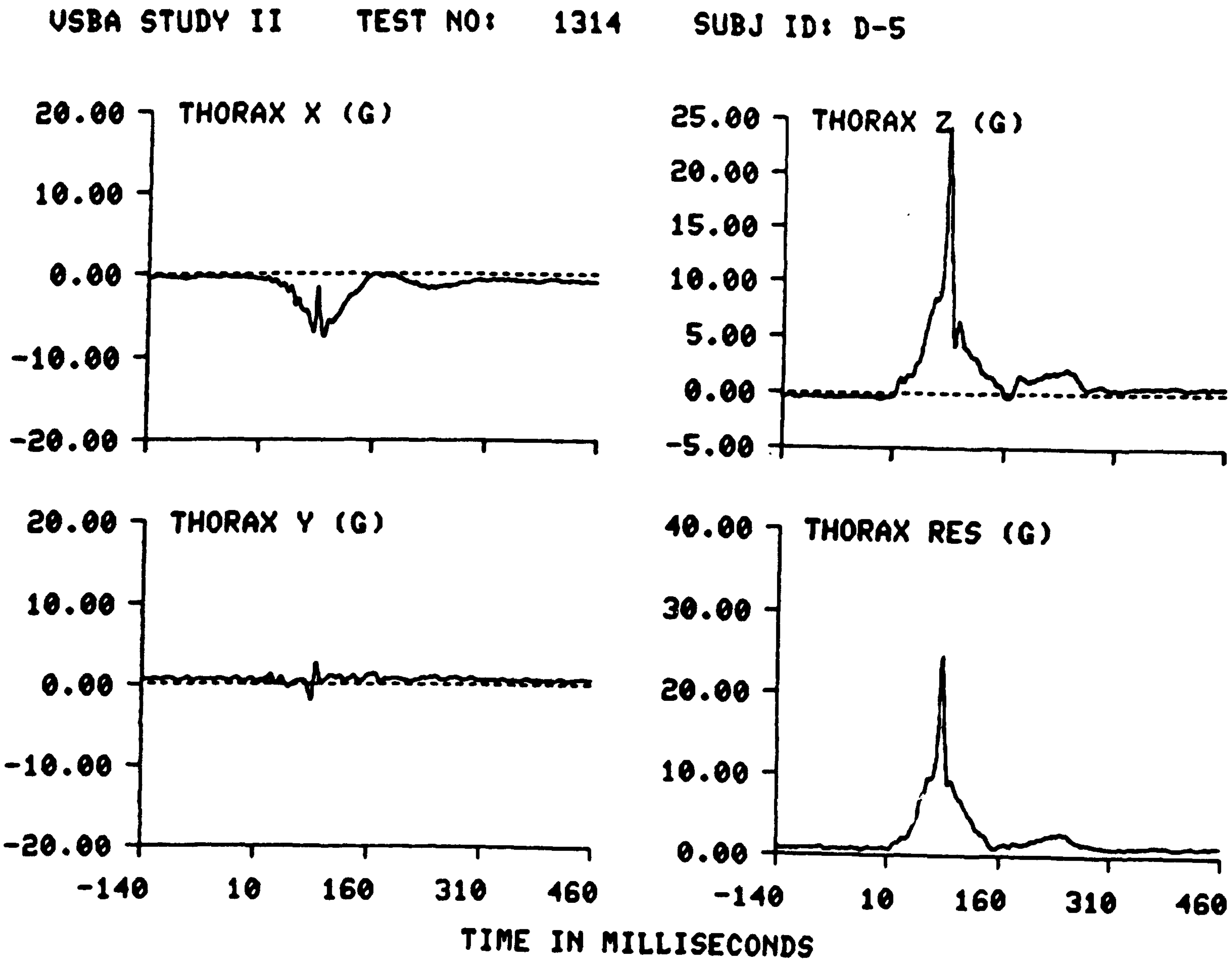



USBA STUDY II TEST NO: 1314 SUBJ ID: D-5
SEAT X (G)
10.00
5.00
0.00
-5.00
-10.00
SEAT Y (G)
10.00
5.00
0.00
-5.00
-10.00
SEAT Z (G)
15.00
10.00
5.00
0.00
-5.00
-140
10
160
310
460
TIME IN MILLISECONDS

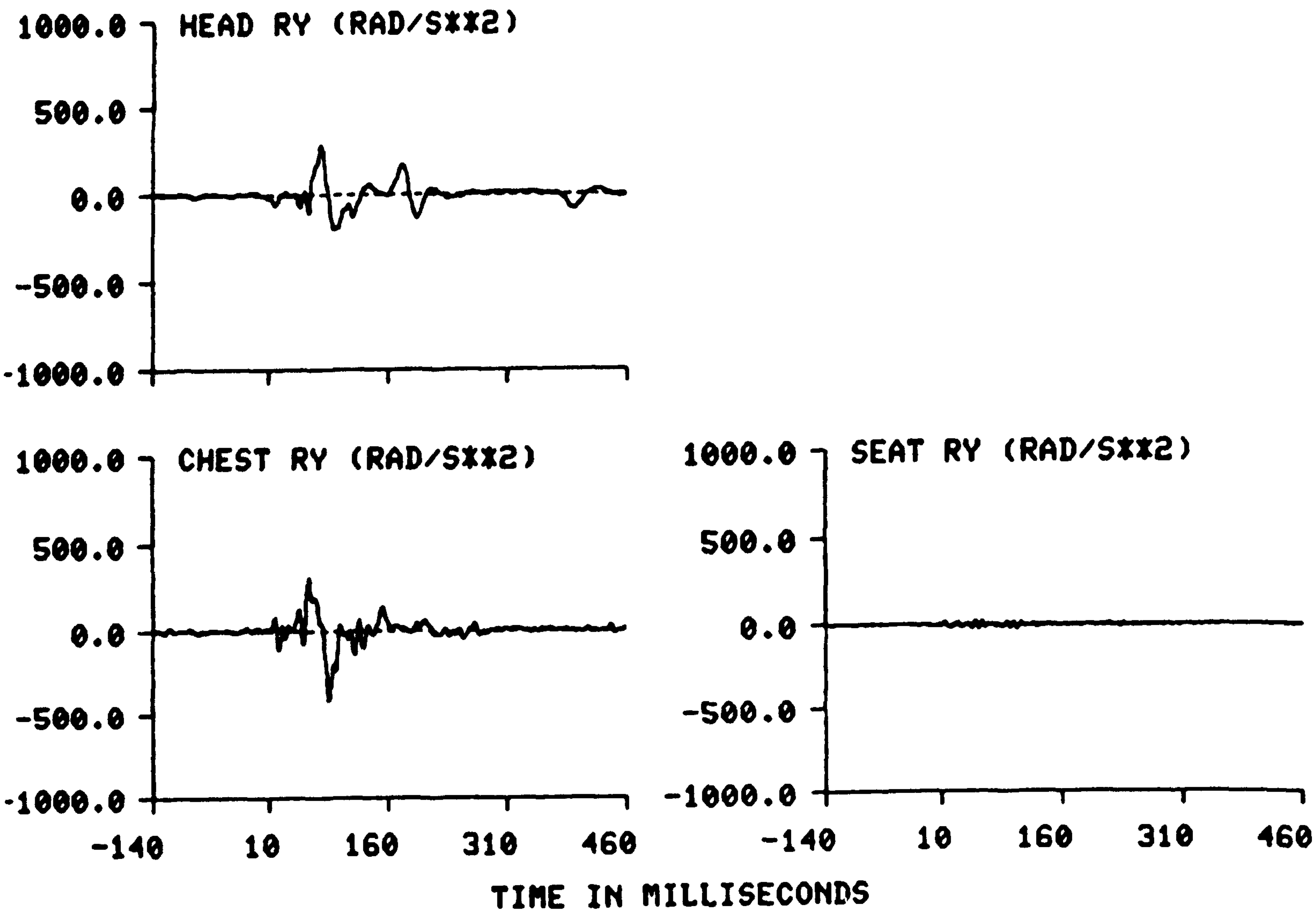

USBA STUDY II TEST NO: 1314 SUBJ ID: D-5
CHEST X (G)
15.00
5.00
-5.00
-15.00
CHEST Z (G)
20.00
10.00
0.00
-10.00
CHEST Y (G)
15.00
5.00
-5.00
-15.00
CHEST RES (G)
30.00
20.00
10.00
0.00
-140
10
160
310
460
TIME IN MILLISECONDS

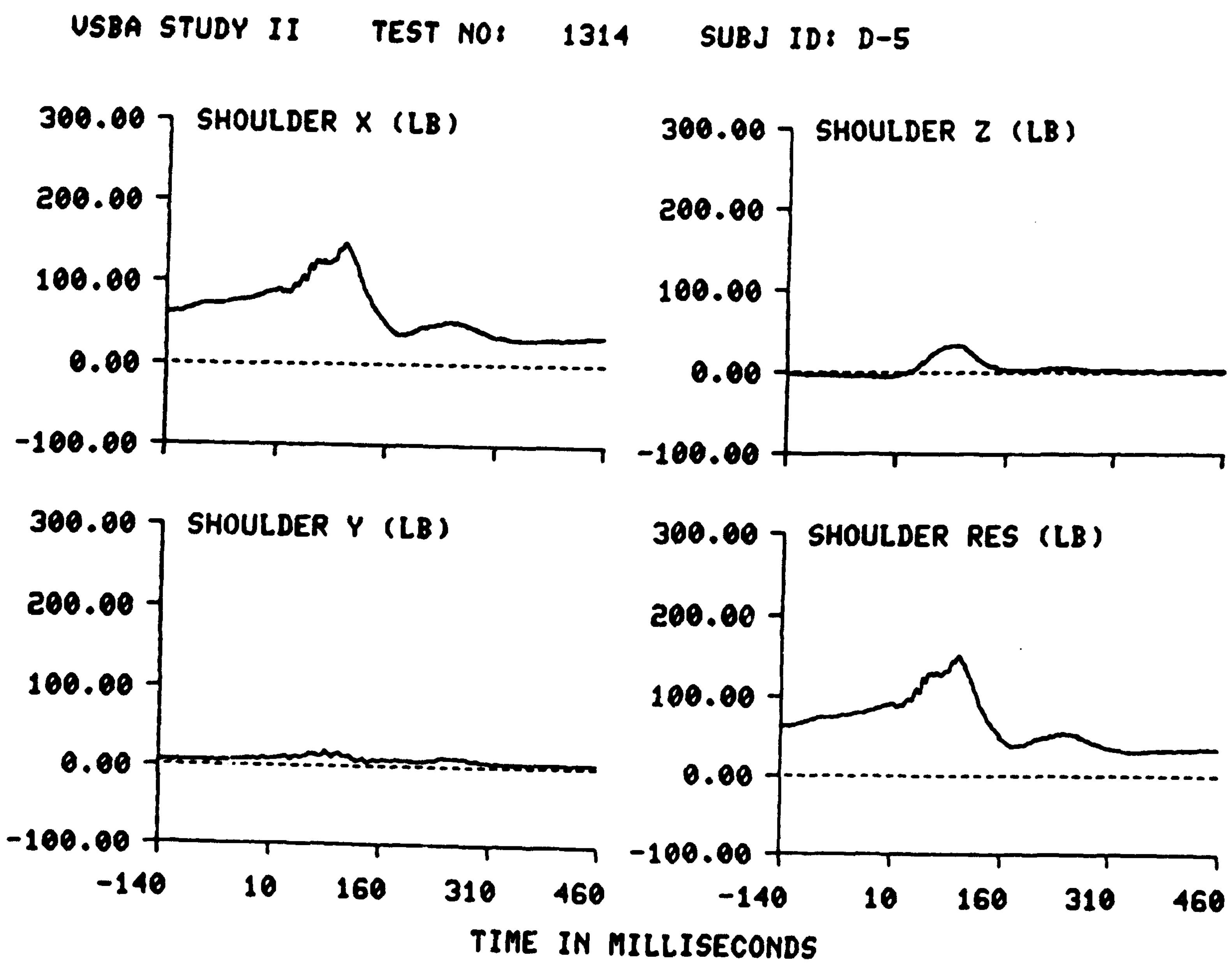


VSBA STUDY II TEST NO: 1314 SUBJ ID: D-5
HEAD X (G)
HEAD Z (G)
HEAD Y (G)
HEAD RES (G)
20.00
10.00
0.00
-10.00
-20.00
40.00
30.00
-140
10
160
310
460
TIME IN MILLISECONDS


USBA STUDY II TEST NO: 1314 SUBJ ID: D-5
THORAX X (G)
THORAX Z (G)
THORAX Y (G)
THORAX RES (G)
20.00
10.00
0.00
-10.00
-20.00
25.00
15.00
5.00
-5.00
40.00
30.00
-140
10
160
310
460
TIME IN MILLISECONDS

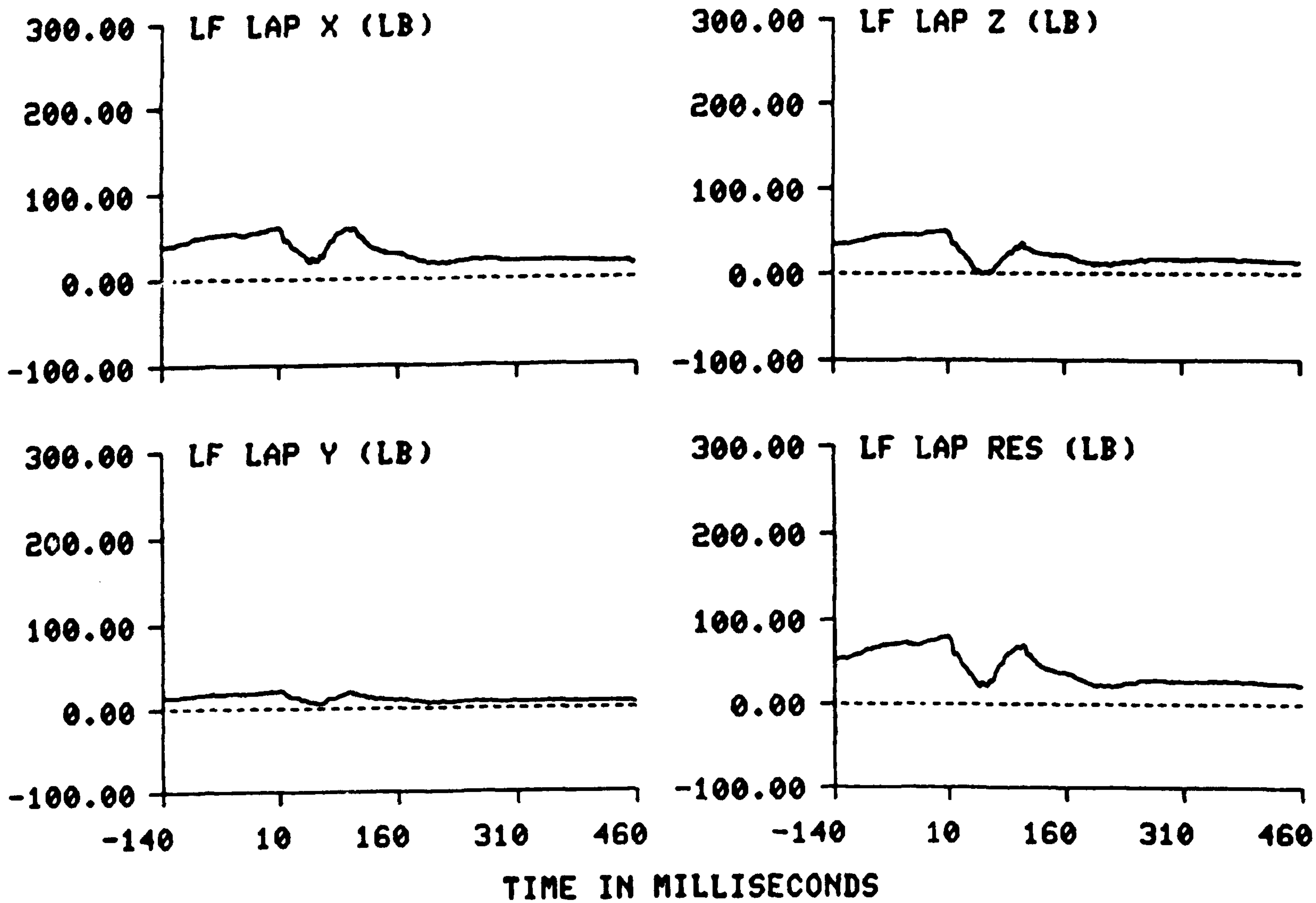
USBA STUDY II TEST NO: 1314 SUBJ ID: D-5

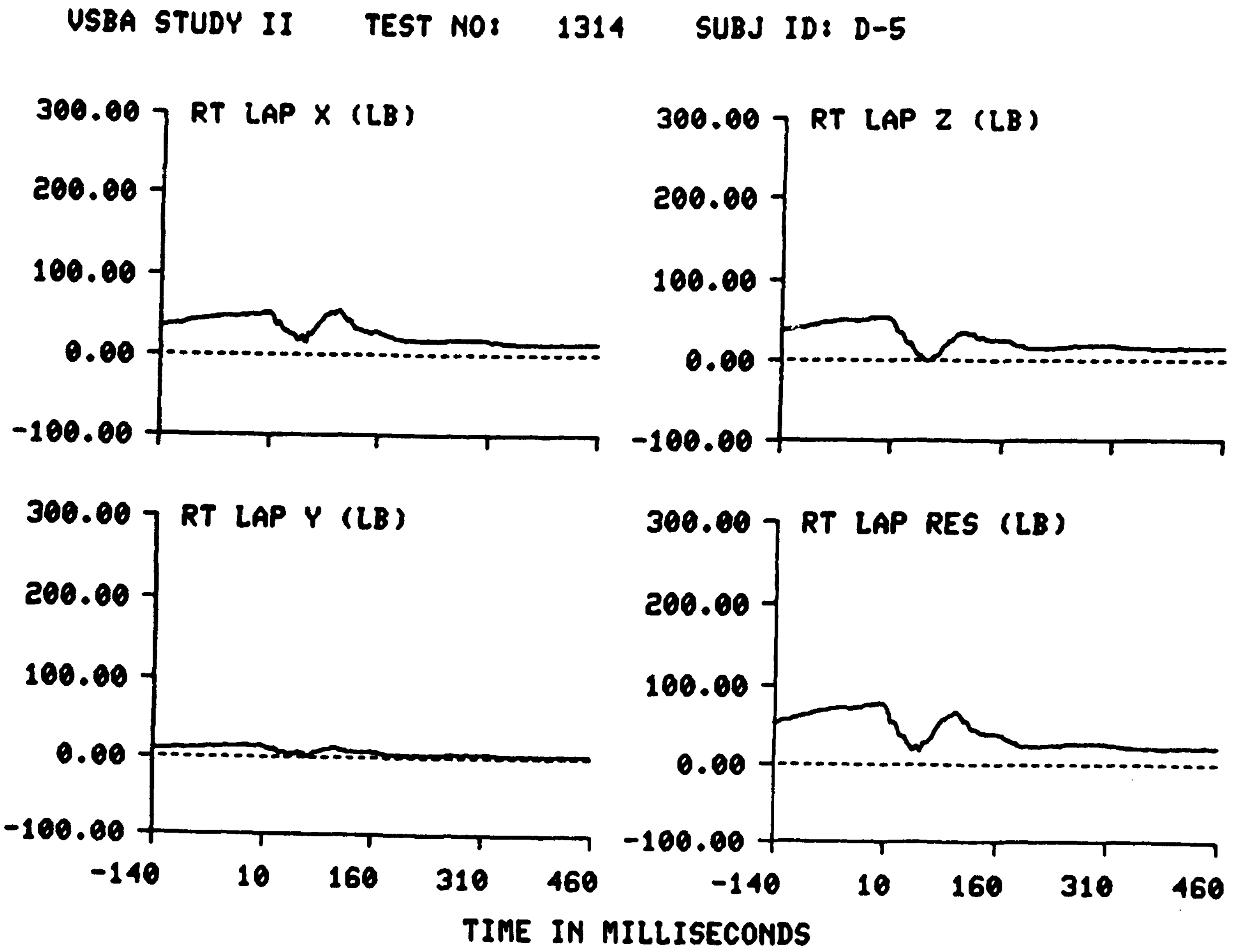




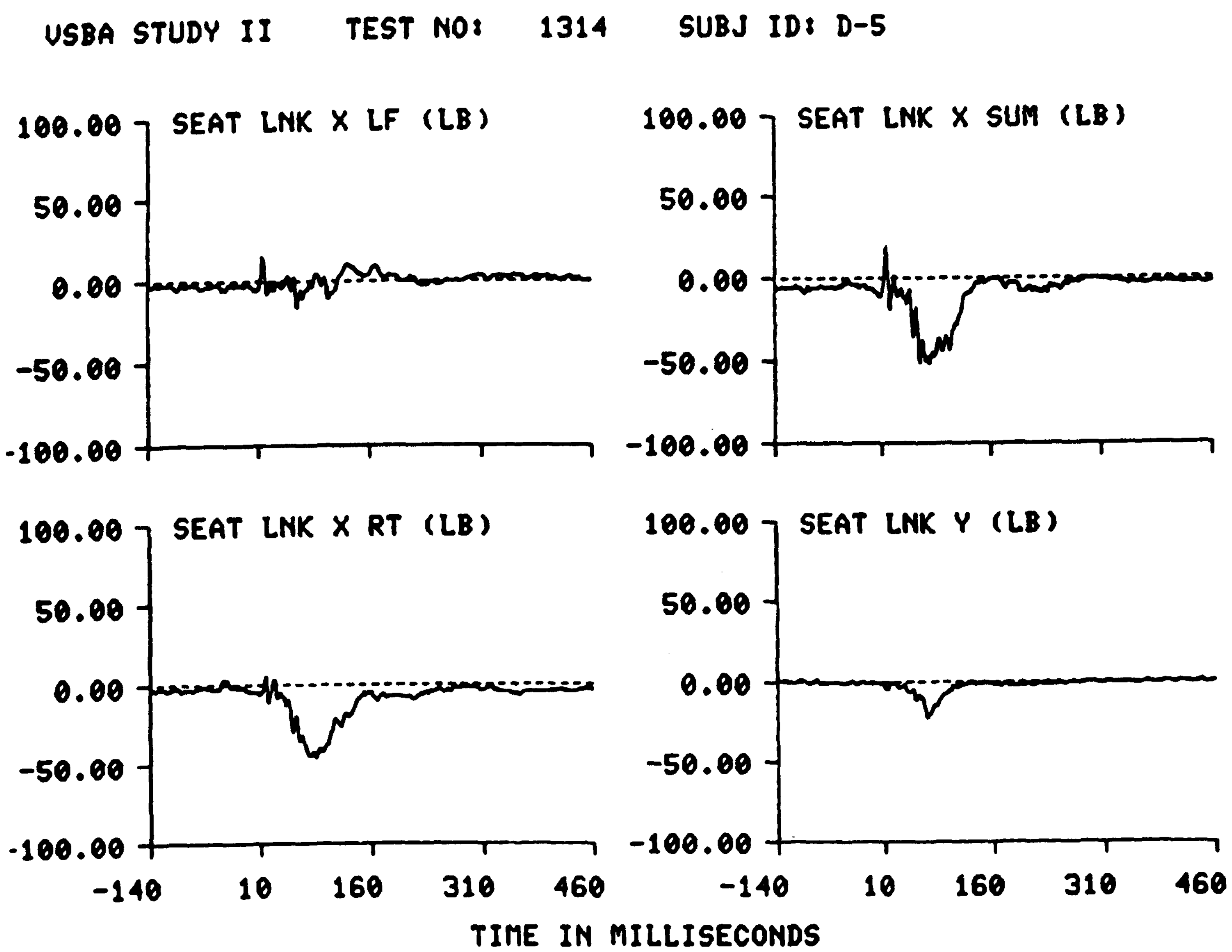
USBA STUDY II TEST NO: 1314 SUBJ ID: D-5
SHOULDER X (LB)
SHOULDER Z (LB)
SHOULDER Y (LB)
SHOULDER RES (LB)
300.00
200.00
100.00
0.00
-100.00
-140
10
160
310
460
TIME IN MILLISECONDS

VSBA STUDY II TEST NO: 1314 SUBJ ID: D-5

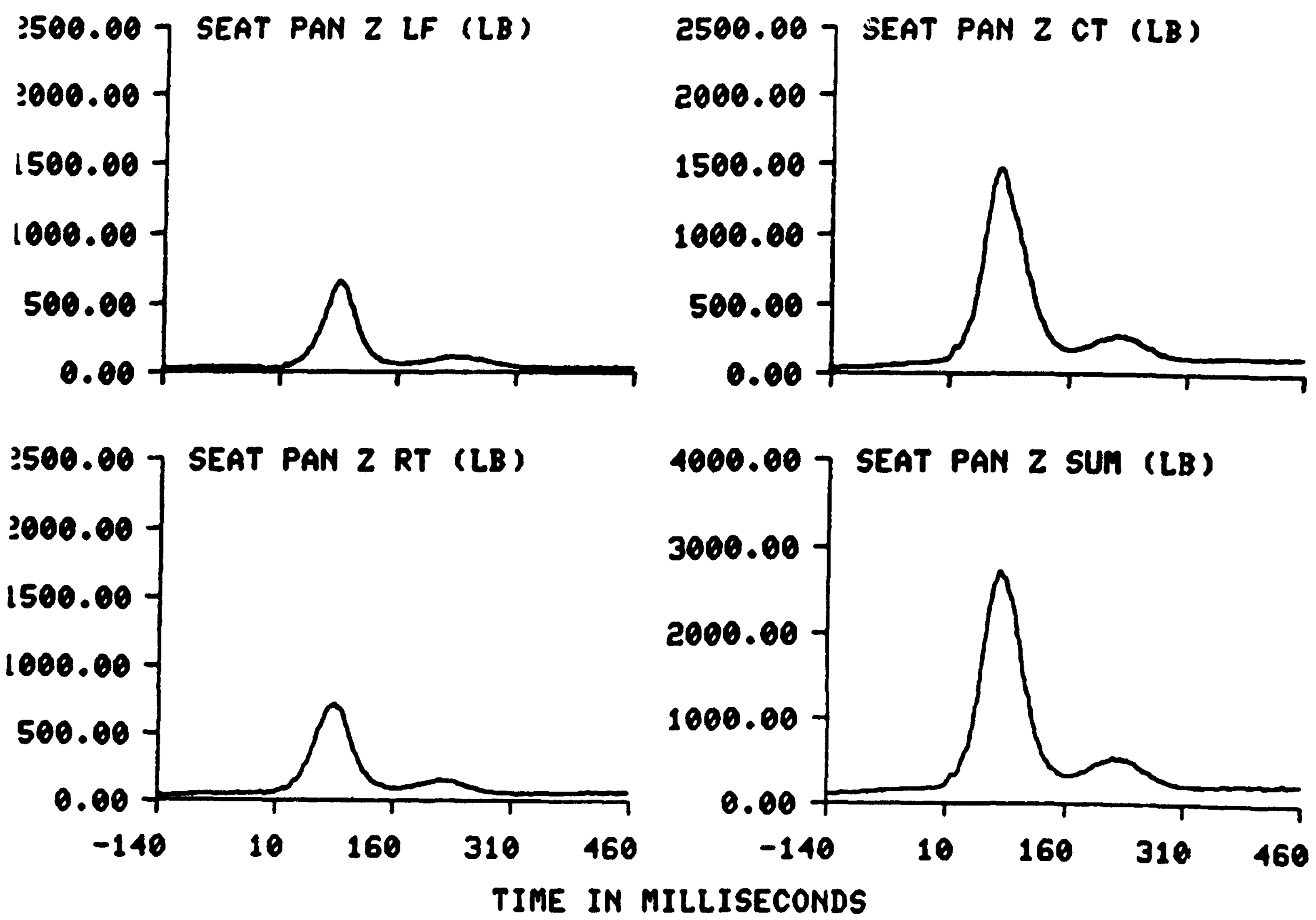


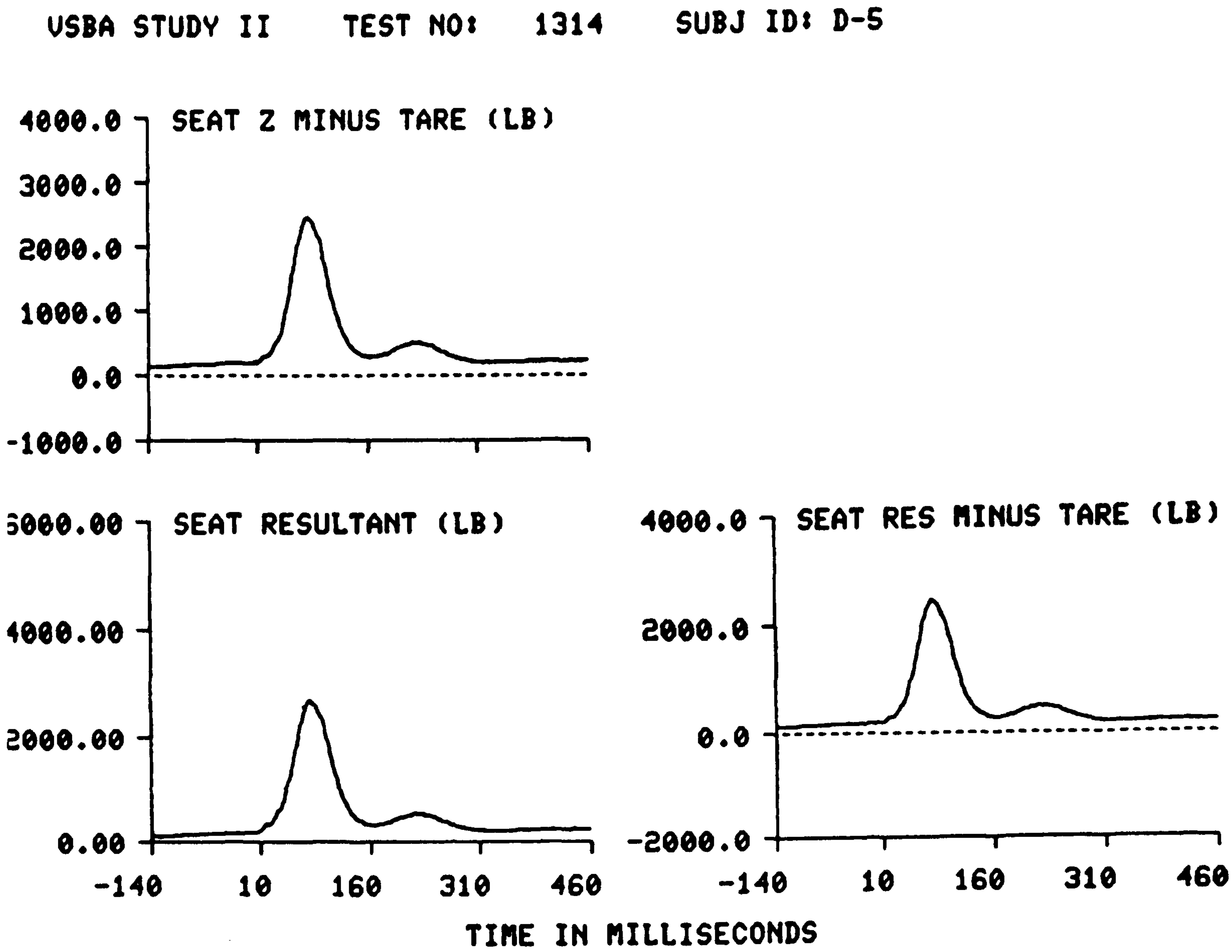


VSBA STUDY II
TEST NO: 1314
SUBJ ID: D-5
RT LAP X (LB)
RT LAP Z (LB)
RT LAP Y (LB)
RT LAP RES (LB)
300.00
200.00
100.00
0.00
-100.00
-140
10
160
310
460
TIME IN MILLISECONDS


USBA STUDY II
TEST NO: 1314
SUBJ ID: D-5
SEAT LNK X LF (LB)
SEAT LNK X SUM (LB)
SEAT LNK X RT (LB)
SEAT LNK Y (LB)
100.00
50.00
0.00
-50.00
-100.00
-140
10
160
310
460
TIME IN MILLISECONDS

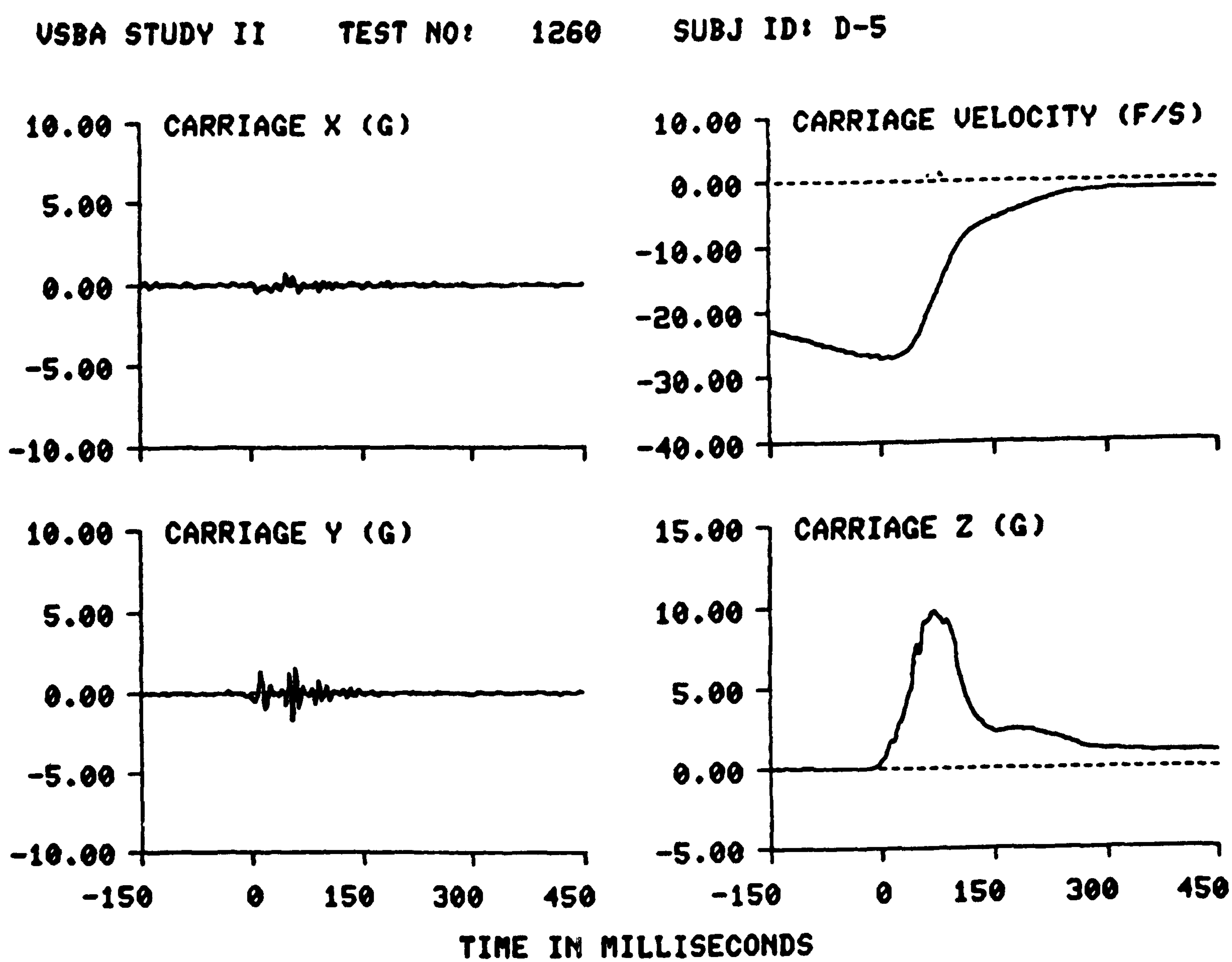
USBA STUDY II TEST NO: 1314 SUBJ ID: D-5

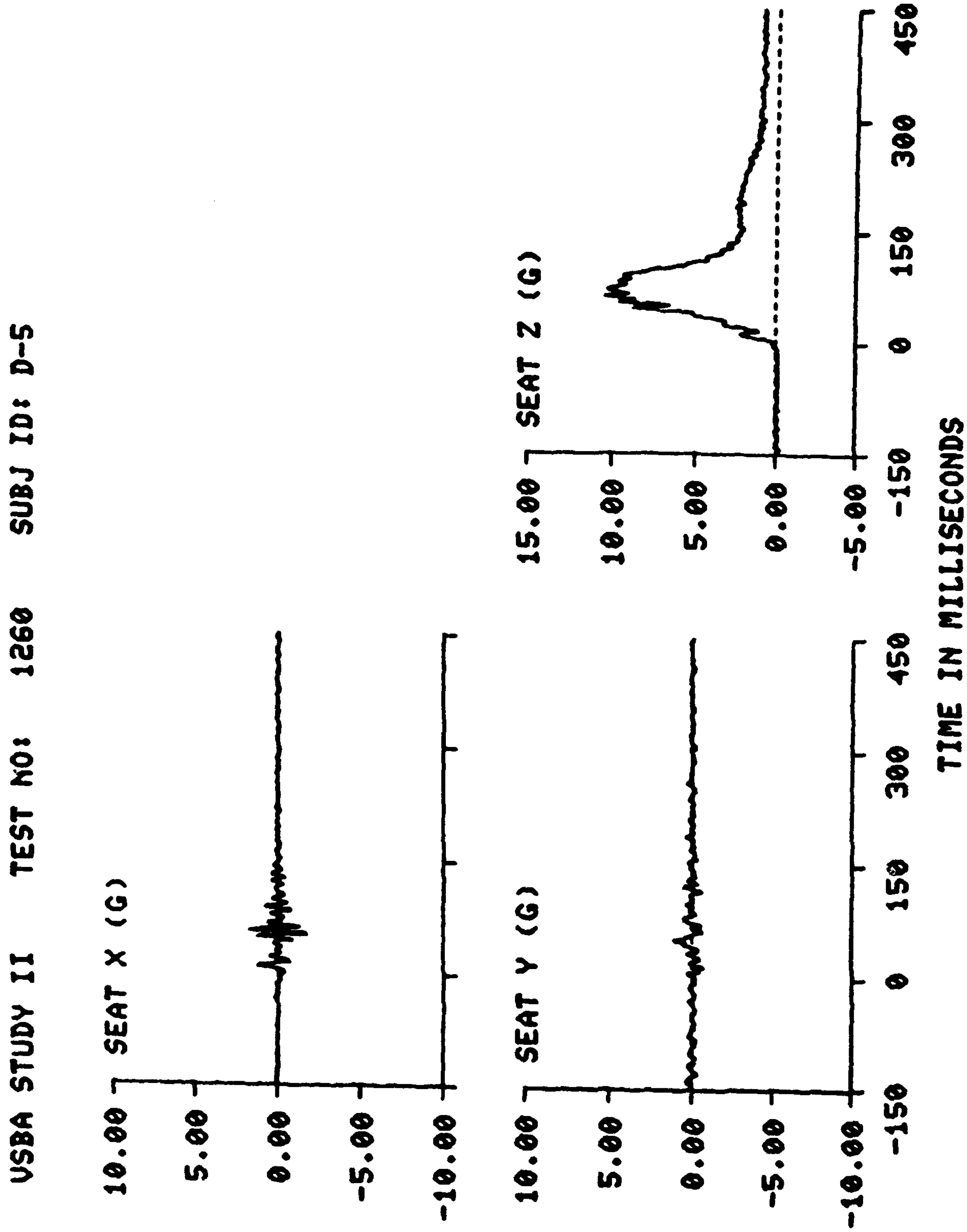


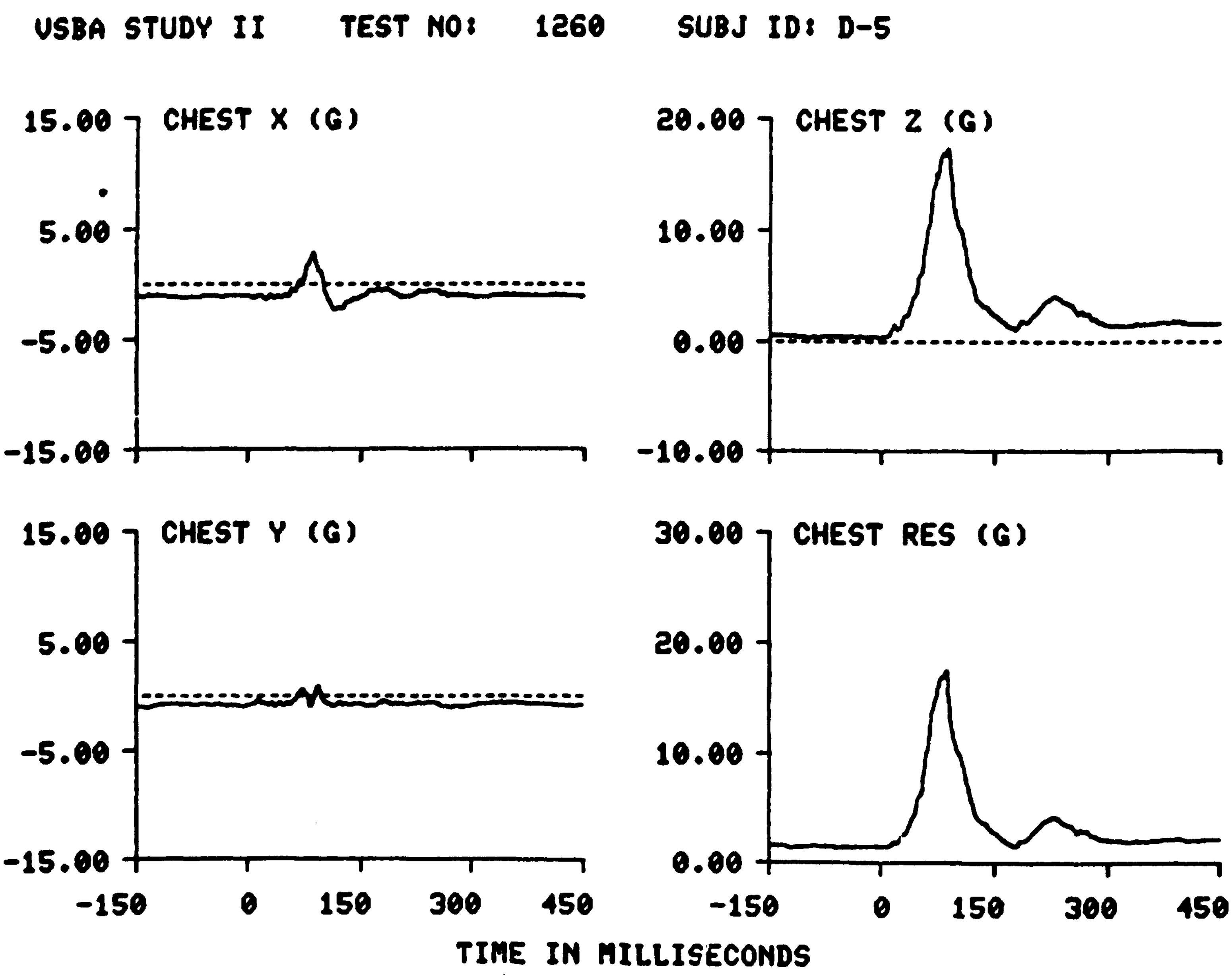

USBA STUDY II TEST NO: 1314 SUBJ ID: D-5
SEAT Z MINUS TARE (LB)
4000.0
3000.0
2000.0
1000.0
0.0
-1000.0
SEAT RESULTANT (LB)
6000.00
4000.00
2000.00
0.00
SEAT RES MINUS TARE (LB)
4000.0
2000.0
0.0
-2000.0
-140
10
160
310
460
TIME IN MILLISECONDS

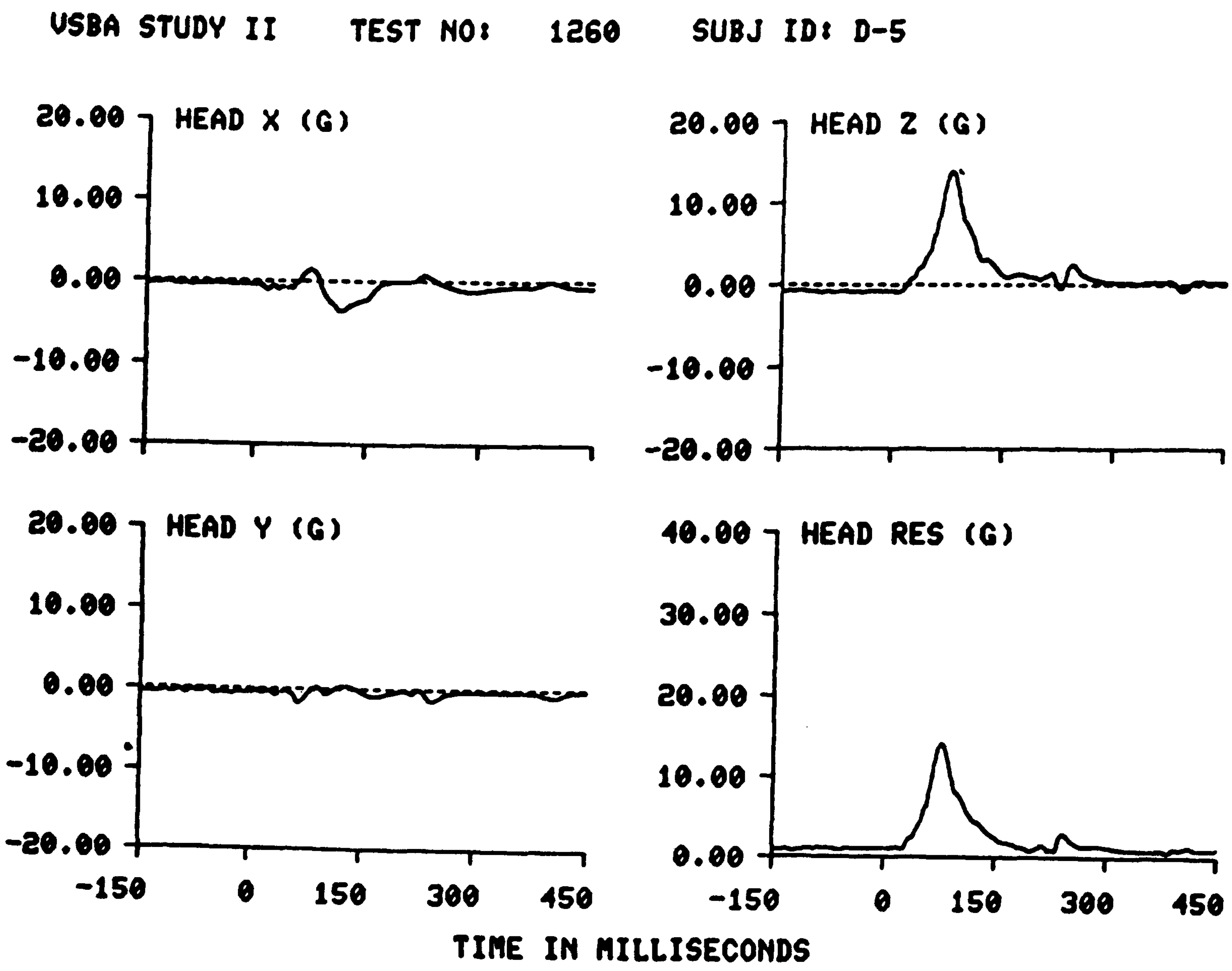
VSBA STUDY II TEST: 1260 SUBJ: D-5 WT: 172.0 NOM G: 10.0 CELL: H

DATA ID	IMMEDIATE PREIMPACT	MAXIMUM VALUE	MINIMUM VALUE	TIME OF MAXIMUM	TIME OF MINIMUM
REFERENCE MARK				-150.	
2.5V EXT PWR		2.50	2.50	11.	0.
10V EXT PWR		10.01	9.99	242.	128.
CARRIAGE ACCELERATION (G)					
X AXIS	0.04	0.75	-0.48	45.	7.
Y AXIS	-0.11	1.59	-1.74	58.	54.
Z AXIS	0.02	9.80	0.48	69.	0.
Z AXIS (SM)	0.04	9.59	0.49	70.	0.
SEAT ACCELERATION (G)					
X AXIS	-0.02	1.69	-1.77	58.	53.
Y AXIS	-0.03	1.05	-0.74	52.	15.
Z AXIS	-0.14	10.34	0.16	62.	0.
Z AXIS (SM)	-0.13	9.90	0.20	72.	0.
RY	-8.54	15.22	-31.42	46.	51.
CARRIAGE VELOCITY (F/S)	-26.65	-1.21	-27.29	357.	1.
CHEST ACCELERATION (G)					
X AXIS	-1.04	2.84	-2.34	86.	114.
Y AXIS	-0.90	0.89	-1.03	92.	273.
Z AXIS	0.48	17.25	0.49	86.	4.
RESULTANT	1.46	17.49	1.42	86.	176.
NORM RESULTANT	0.15	1.82	0.15	86.	176.
SI		43.65			
RY	-3.96	257.56	-399.03	72.	94.
HEAD ACCELERATION (G)					
X AXIS	-0.38	1.43	-3.72	74.	115.
Y AXIS	-0.53	0.35	-1.73	127.	67.
Z AXIS	-0.75	13.84	-0.88	76.	7.
RESULTANT	1.00	13.94	0.52	76.	383.
NORM RESULTANT	0.10	1.45	0.05	76.	383.
SI		22.28			
RY	-1.78	141.56	-184.06	75.	225.
THORAX ACCELERATION (G)					
X AXIS	-1.27	-0.30	-9.72	170.	105.
Y AXIS	0.30	3.73	-0.15	93.	21.
Z AXIS	0.30	21.12	-0.47	82.	172.
RESULTANT	1.35	21.85	0.47	82.	170.
NORM RESULTANT	0.14	2.28	0.05	82.	170.
SHOULDER LOADS (LB)					
X AXIS	61.52	145.48	23.11	106.	337.
Y AXIS	4.61	13.46	0.56	105.	407.
Z AXIS	-9.78	24.15	-9.27	90.	0.
RESULTANT	62.46	147.08	23.35	106.	337.
LAP LOADS (LB)					
LEFT X AXIS	82.62	85.03	12.99	0.	401.
LEFT Y AXIS	27.38	28.17	5.86	1.	378.
LEFT Z AXIS	68.35	69.15	6.99	0.	62.
LEFT RESULTANT	110.67	113.16	17.59	2.	401.
RIGHT X AXIS	63.75	65.12	10.85	1.	381.
RIGHT Y AXIS	18.21	18.56	1.75	0.	410.
RIGHT Z AXIS	63.79	63.72	2.47	0.	57.
RIGHT RESULTANT	92.01	92.85	17.68	3.	379.
SEAT LOADS (LB)					
LEFT LINK X AXIS	-4.32	8.98	-9.10	58.	45.
RIGHT LINK X AXIS	-4.40	3.07	-44.66	48.	85.
X AXIS	-8.73	2.51	-51.96	11.	84.
CENTER LINK Y AXIS	-0.02	0.63	-1.27	9.	90.
LEFT PAN Z AXIS	94.68	623.97	44.18	76.	330.
RIGHT PAN Z AXIS	85.49	748.70	51.96	78.	362.
CENTER PAN Z AXIS	58.88	1271.15	68.04	76.	0.
Z AXIS SUM	239.05	2640.71	188.94	76.	328.
Z AXIS MINUS TARE	271.18	2401.73	131.16	77.	333.
RESULTANT	239.21	2641.09	189.01	76.	328.
RESULTANT MINUS TARE	271.32	2402.13	191.23	77.	333.

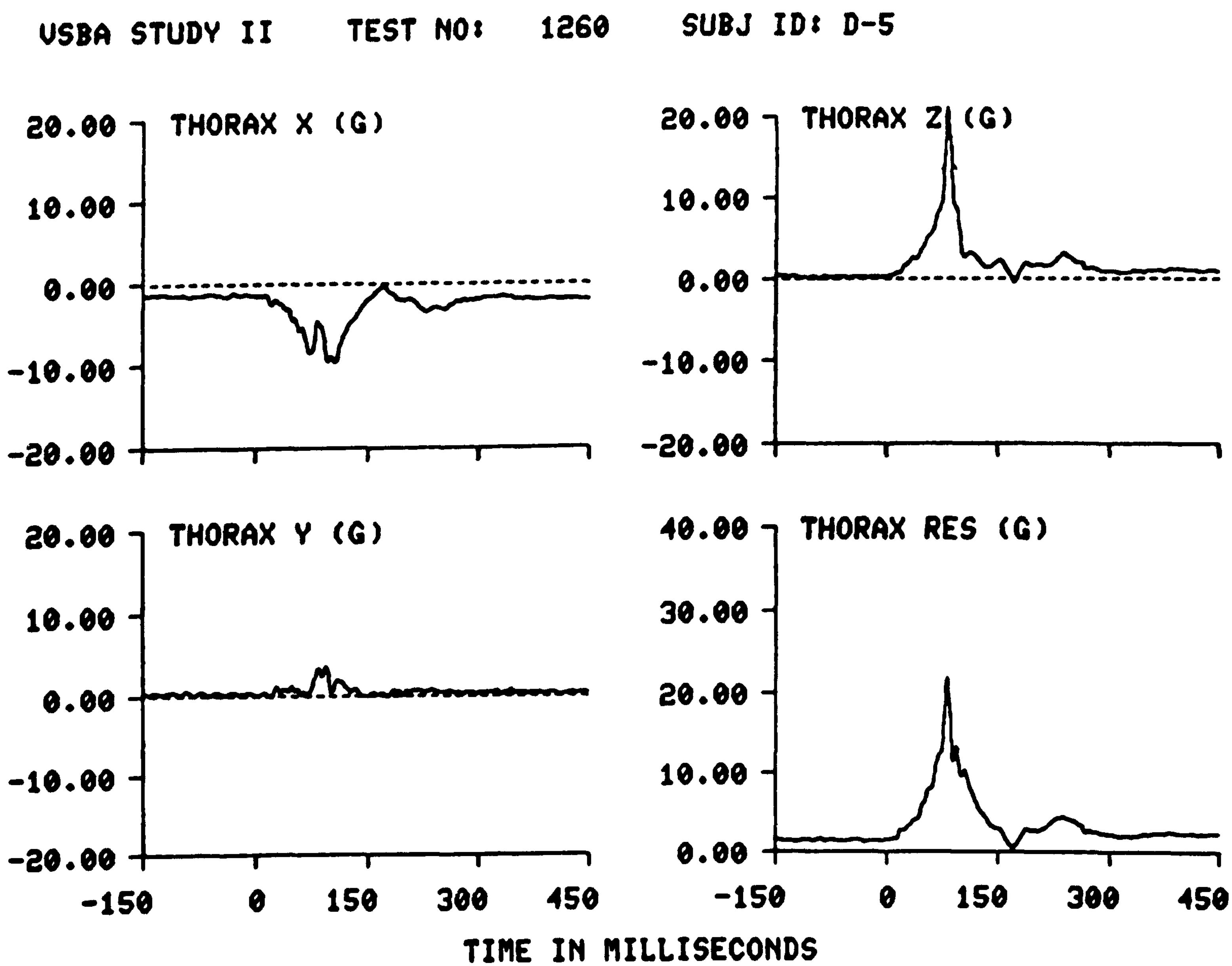

USBA STUDY II TEST NO: 1260 SUBJ ID: D-5
CARRIAGE X (G)
CARRIAGE VELOCITY (F/S)
CARRIAGE Y (G)
CARRIAGE Z (G)
10.00
5.00
0.00
-5.00
-10.00
-20.00
-30.00
-40.00
15.00
-150
0
150
300
450
TIME IN MILLISECONDS


USBA STUDY II
TEST NO: 1260
SUBJ ID: D-5
SEAT X (G)
SEAT Y (G)
SEAT Z (G)
10.00
5.00
0.00
-5.00
-10.00
15.00
-150
0
150
300
450
TIME IN MILLISECONDS

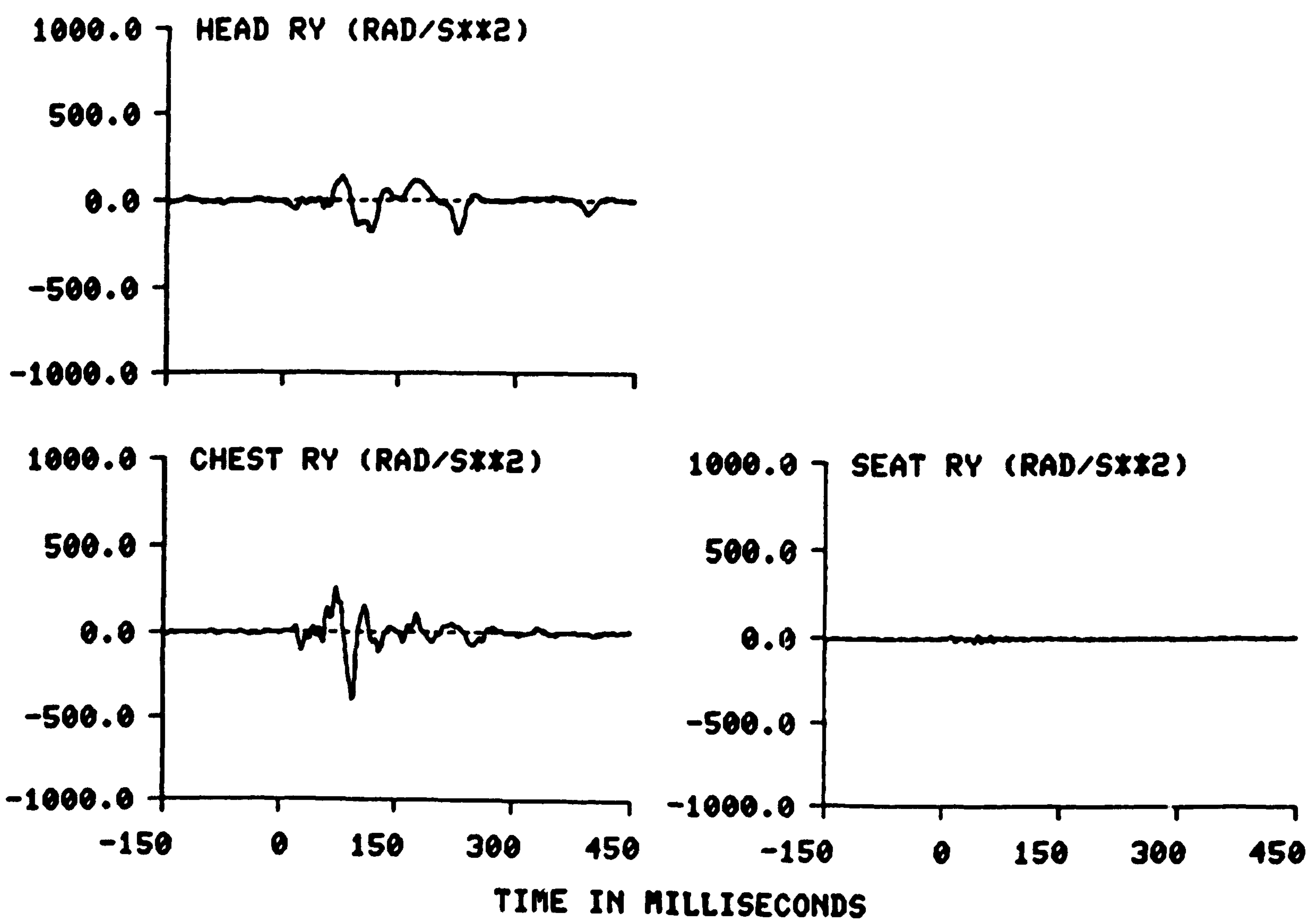

USBA STUDY II TEST NO: 1260 SUBJ ID: D-5
CHEST X (G)
15.00
5.00
-5.00
-15.00
CHEST Z (G)
20.00
10.00
0.00
-10.00
CHEST Y (G)
15.00
5.00
-5.00
-15.00
CHEST RES (G)
30.00
20.00
10.00
0.00
-150
0
150
300
450
-150
0
150
300
450
TIME IN MILLISECONDS

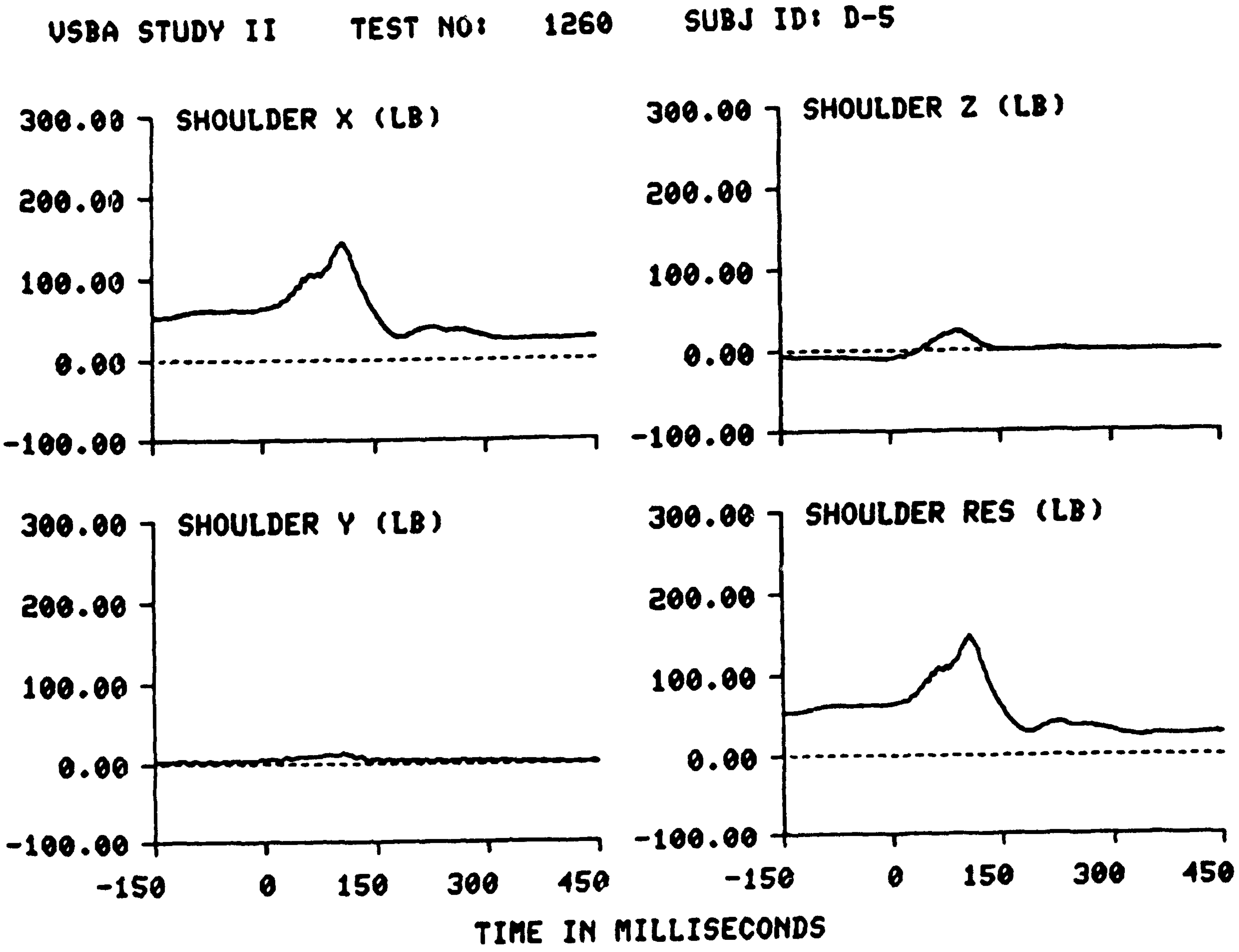


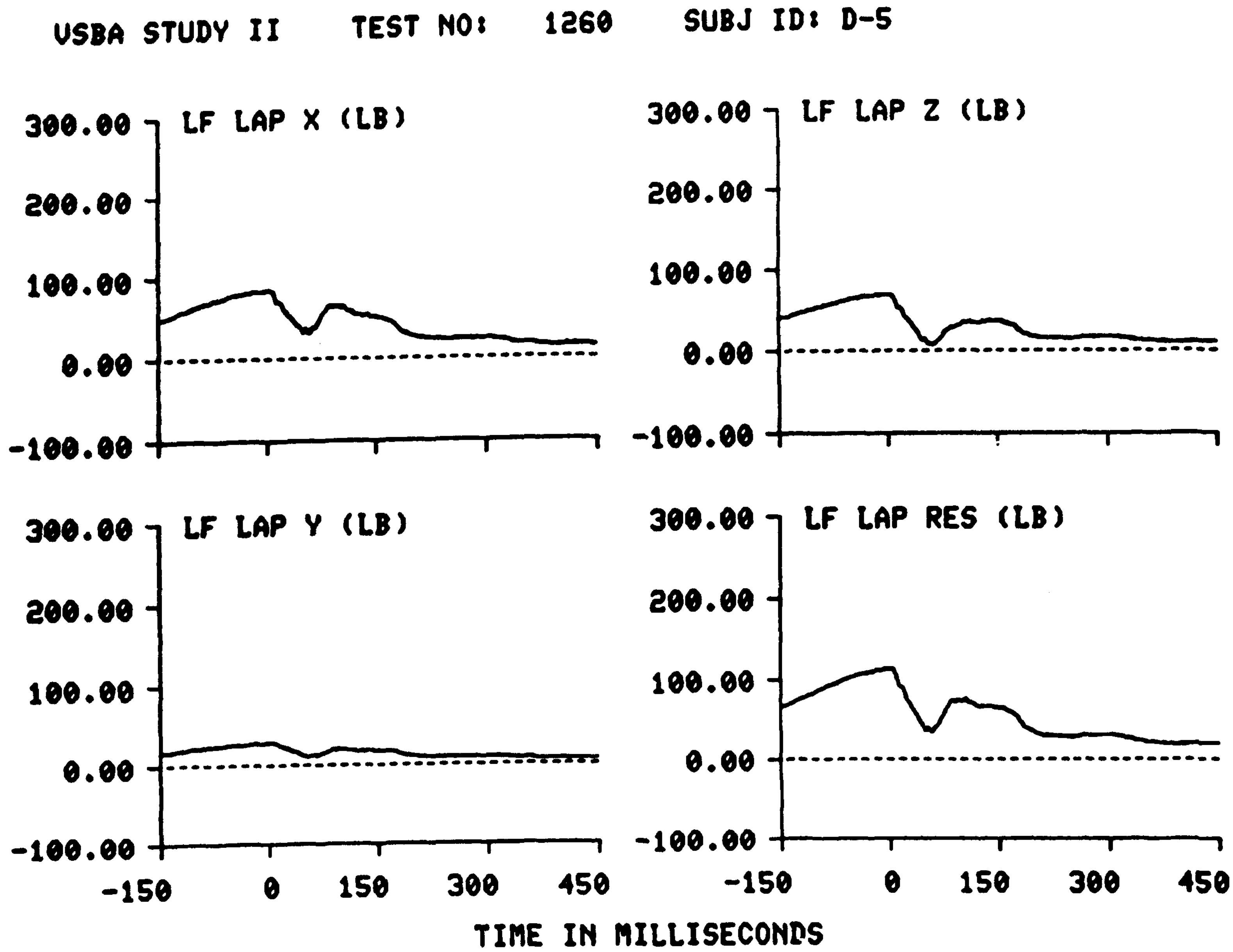
USBA STUDY II TEST NO: 1260 SUBJ ID: D-5
HEAD X (G)
HEAD Z (G)
HEAD Y (G)
HEAD RES (G)
20.00
10.00
0.00
-10.00
-20.00
40.00
30.00
-150
0
150
300
450
TIME IN MILLISECONDS


USBA STUDY II TEST NO: 1260 SUBJ ID: D-5
THORAX X (G)
THORAX Z (G)
THORAX Y (G)
THORAX RES (G)
20.00
10.00
0.00
-10.00
-20.00
40.00
30.00
-150
0
150
300
450
TIME IN MILLISECONDS

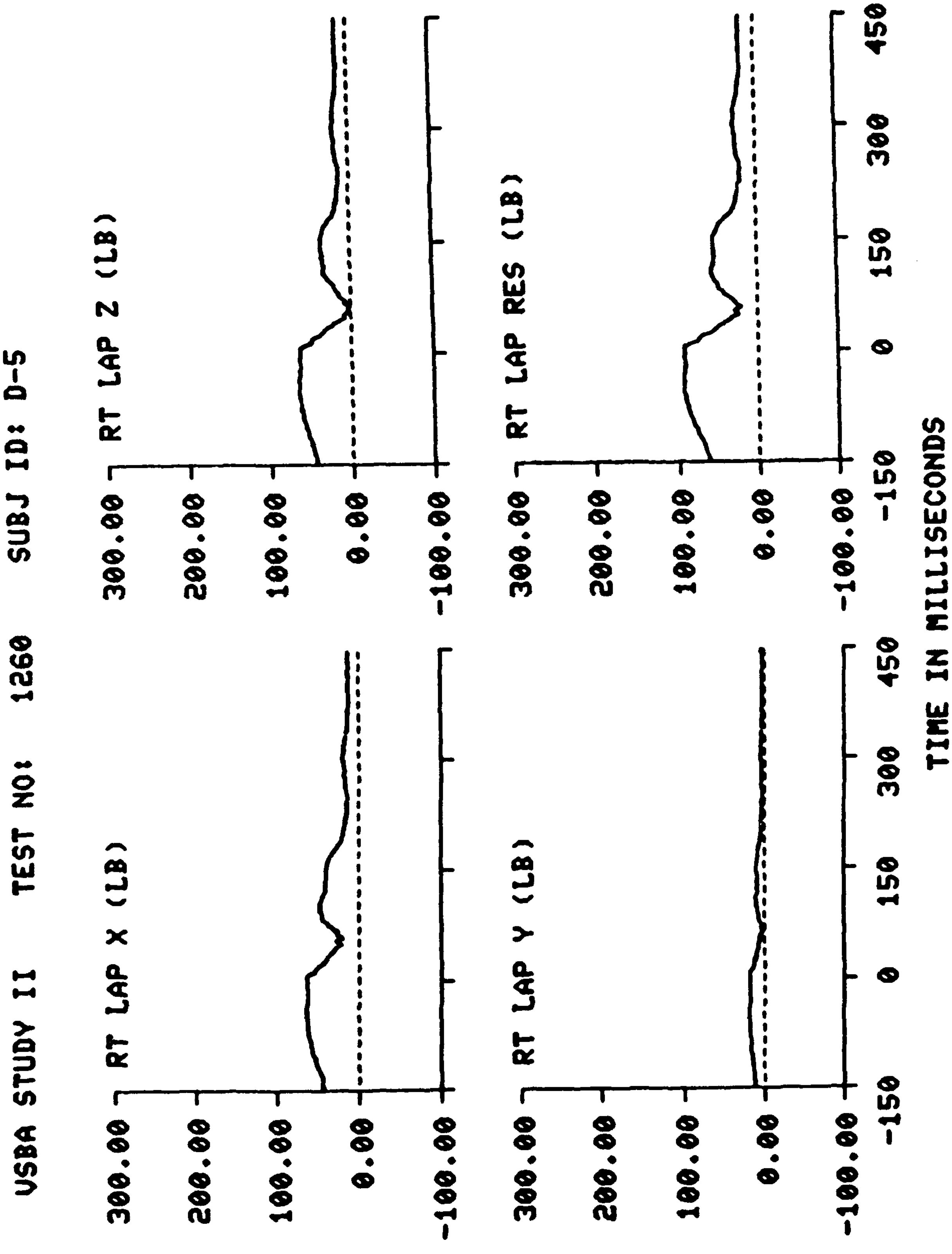
USBA STUDY II   TEST NO: 1260   SUBJ ID: D-5



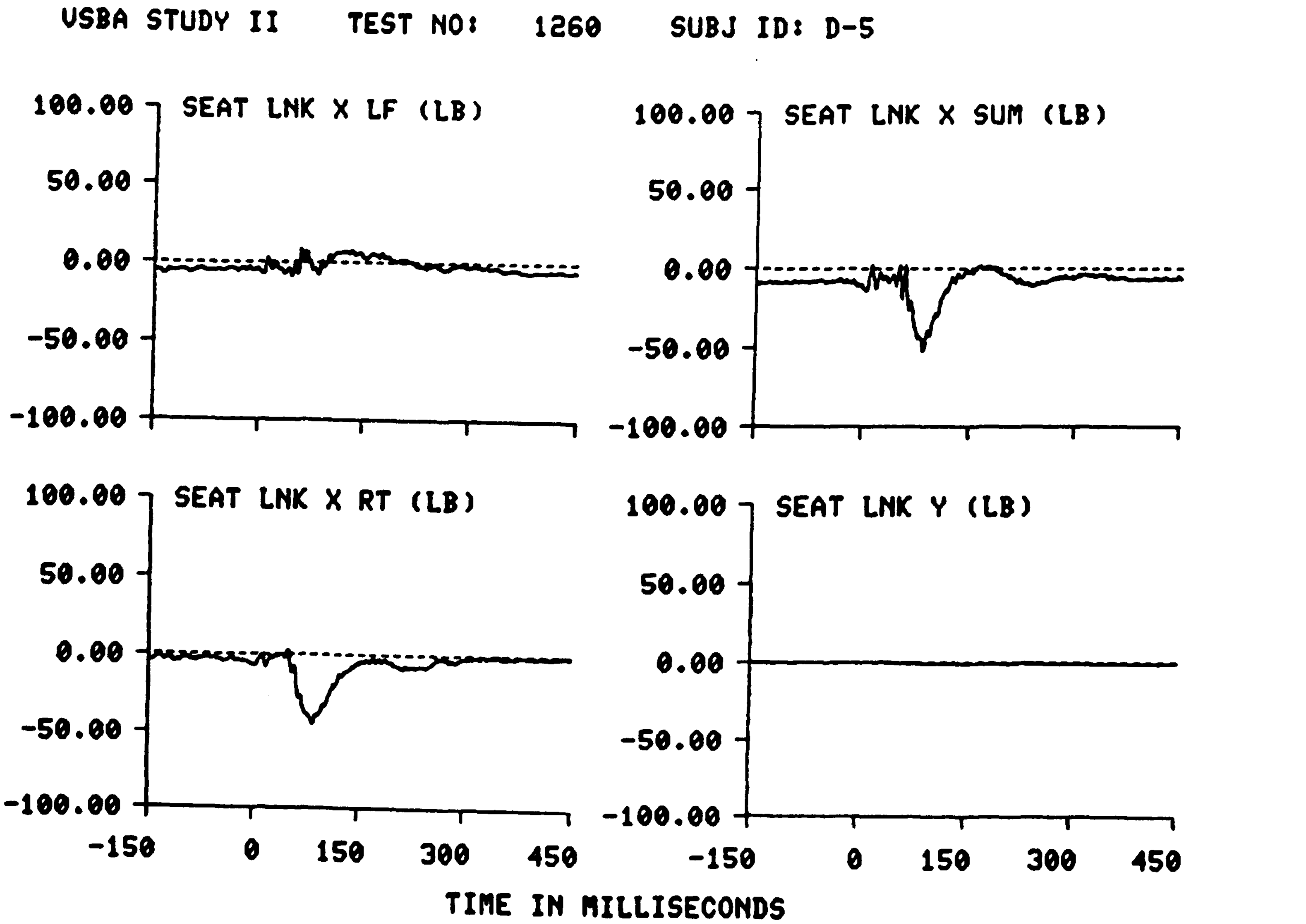

USBA STUDY II TEST NO: 1260 SUBJ ID: D-5
SHOULDER X (LB)
SHOULDER Z (LB)
SHOULDER Y (LB)
SHOULDER RES (LB)
300.00
200.00
100.00
0.00
-100.00
-150
0
150
300
450
TIME IN MILLISECONDS



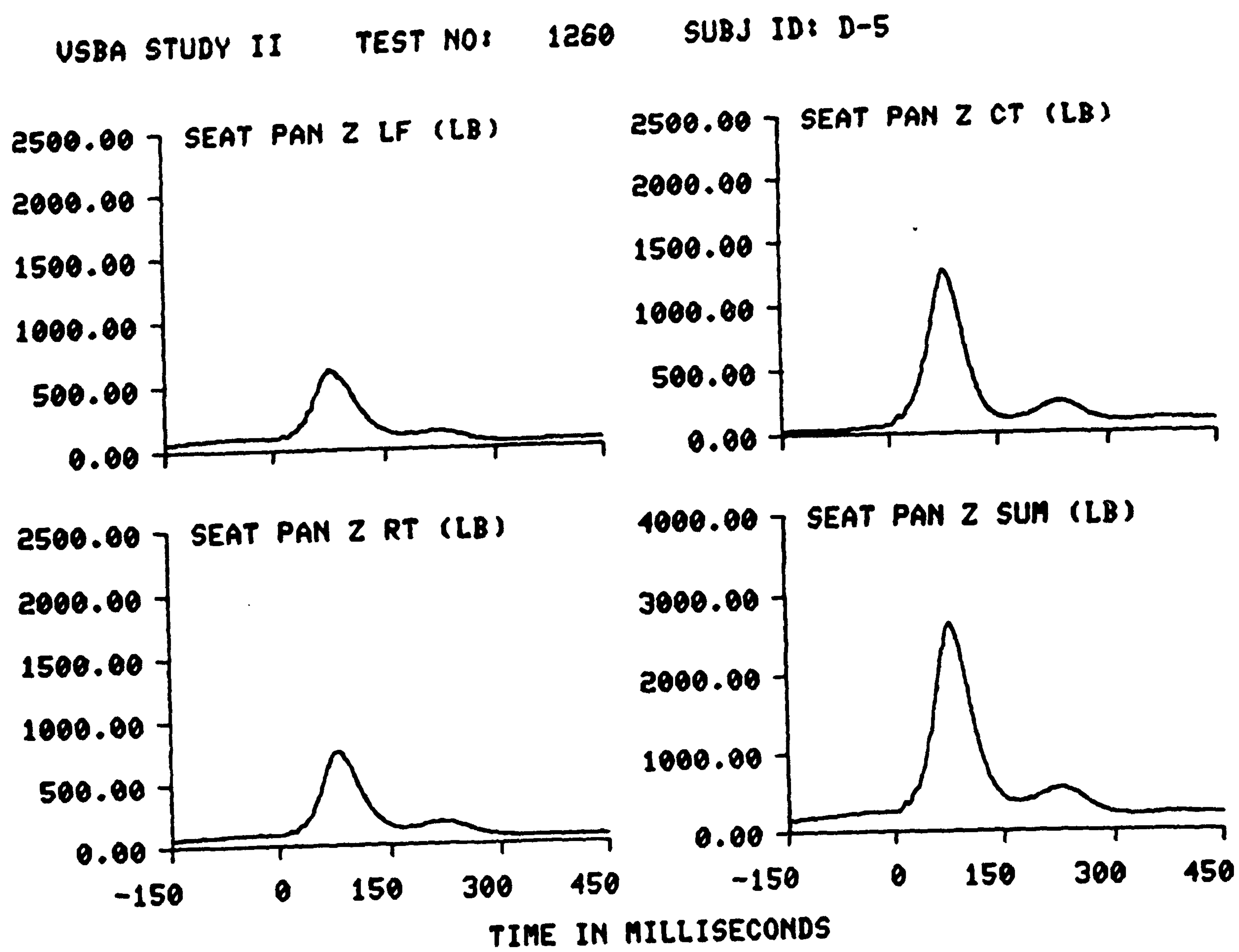
USBA STUDY II TEST NO: 1260 SUBJ ID: D-5
LF LAP X (LB)
LF LAP Z (LB)
LF LAP Y (LB)
LF LAP RES (LB)
300.00
200.00
100.00
0.00
-100.00
-150
0
150
300
450
TIME IN MILLISECONDS



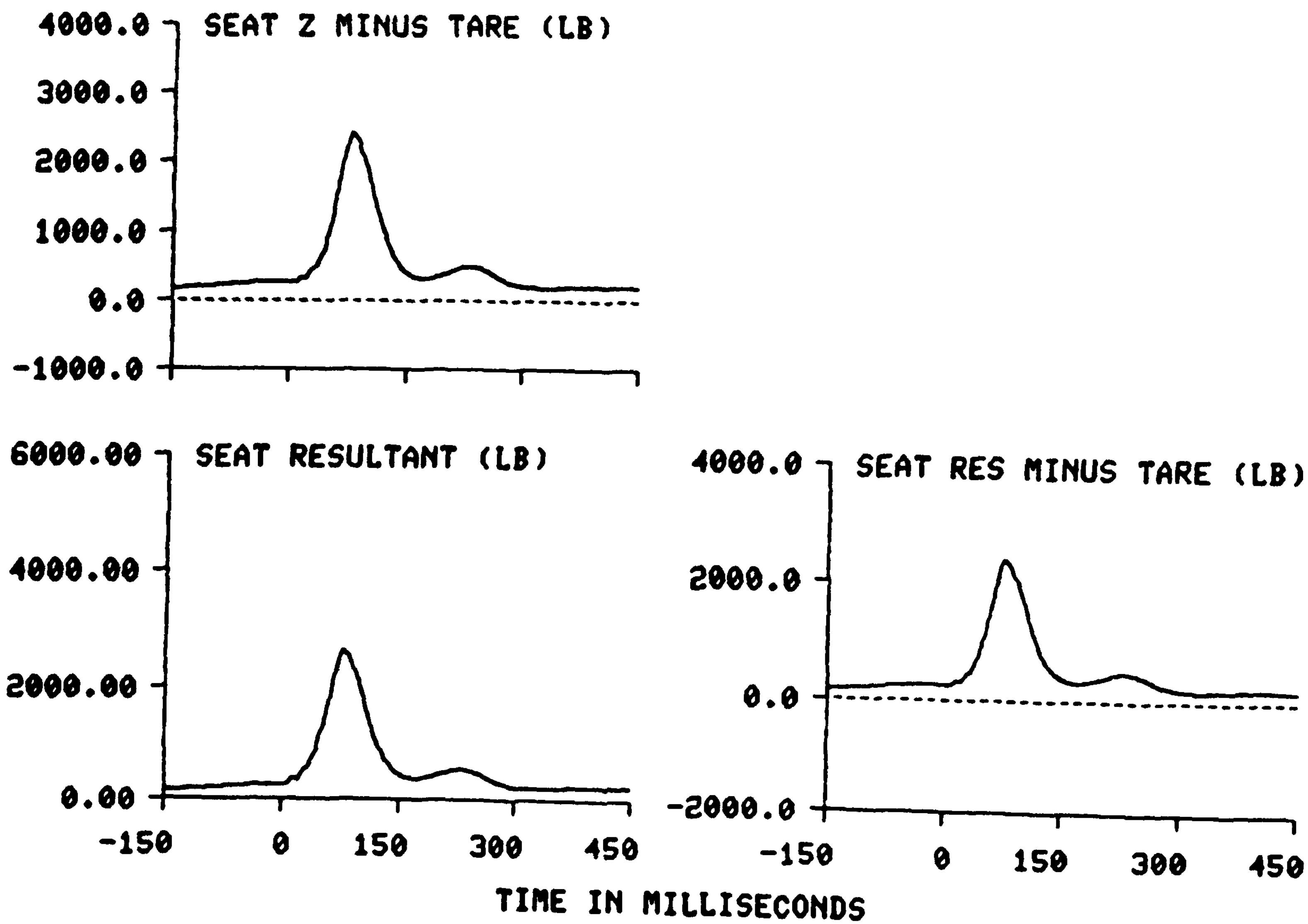
USBA STUDY II TEST NO: 1260 SUBJ ID: D-5
RT LAP X (LB)
RT LAP Z (LB)
RT LAP Y (LB)
RT LAP RES (LB)
300.00
200.00
100.00
0.00
-100.00
-150
0
150
300
450
TIME IN MILLISECONDS



USBA STUDY II
TEST NO: 1260
SUBJ ID: D-5
SEAT LNK X LF (LB)
SEAT LNK X SUM (LB)
SEAT LNK X RT (LB)
SEAT LNK Y (LB)
100.00
50.00
0.00
-50.00
-100.00
-150
0
150
300
450
TIME IN MILLISECONDS


USBA STUDY II TEST NO: 1260 SUBJ ID: D-5
SEAT PAN Z LF (LB)
SEAT PAN Z CT (LB)
SEAT PAN Z RT (LB)
SEAT PAN Z SUM (LB)
2500.00
2000.00
1500.00
1000.00
500.00
0.00
4000.00
3000.00
2000.00
1000.00
-150
0
150
300
450
TIME IN MILLISECONDS

VSBA STUDY II TEST NO: 1260 SUBJ ID: D-5



★U.S. Government Printing Office: 1991 — 548-018/40217